Assessment of Presence, Range, and Status of the Northern Myotis (*Myotis septentrionalis*) in the Northern Great Plains of Montana

Prepared for:

US Fish and Wildlife Service, Ecological Services Division

Prepared By:

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Montana Natural Heritage Program

A cooperative program of the Montana State Library and the University of Montana

December 2019

MONTANA Natural Heritage Program

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Document should be cited as:

Bachen, D.A. 2019 Assessment of Presence, Range, and Status of the Northern Myotis (*Myotis septentrionalis*) in the Northern Great Plains of Montana. Montana Natural Heritage Program, Helena, Montana. 16 pp. plus appendices

Executive Summary

The Northern Myotis (*Myotis septentrionalis*, A.K.A Northern Long-Eared Bat) is among the least observed species found within Montana. In 2015 the U.S. Fish and Wildlife Service listed the Northern Myotis as Threatened due to population declines and designated the species as present in nine counties in eastern Montana with an interim special rule under the authority of section 4(d) of the Endangered Species Act of 1973. The change in federal status created a need to understand whether the species was present in the state, its range and habitat associations to aid in management of the species and these habitats. To address this need we implemented a project to:

1. Develop protocols to identify Northern Myotis with certainty and separate similar *Myotis* species
2. Determine if Northern Myotis is present within Montana
3. If present, determine range and use detection data to infer if breeding occurs and if the species is resident or transient within Montana

Our area of interest was across the nine counties designated by the USFWS. Northern Myotis is associated with forested areas, so we chose to target both conifer-dominated uplands and deciduous forest along rivers and streams. Within these habitats, we selected sites based on accessibility, forest presence, and suitable features to survey. Within riparian forest we selected sites with waterbodies where bats could drink within or adjacent to the forest, water shallow enough to net, flyways through wooded areas, and areas of open forest that animals could forage within. In the more xeric conifer forest, we targeted water sources within or adjacent to the forests.

Between 2016 and 2019, we conducted surveys using direct capture (mist net) and acoustic methods across the nine-county designated area in eastern Montana. Our primary method of survey for Northern Myotis was mist nets set over water or across flight paths within wooded areas. We also deployed acoustic detector recorders at sites potentially used by Northern Myotis. In addition to these surveys, this project also supported the genetic confirmation of species identification from guano samples collected at bridges during a concurrent project conducted by NHP with other partners within the area of interest.

Through surveys with mist nets within riparian forest along major rivers we successfully captured Northern Myotis. In 2016, we targeted deciduous riparian woodlands and captured and genetically confirmed three adult Northern Myotis at two sites on the Missouri River. We captured 10 Northern Myotis at two sites during 2017 surveys. In August 2018 we conducted nine nights of mist netting along both the Yellowstone and Missouri Rivers. During this effort we captured six Northern Myotis at three sites. During 2019 we netted eight sites along and south of the Yellowstone River in both riparian forest and Ponderosa pine dominated uplands but did not capture any bats of this species.

We deployed seven acoustic detectors in 2016 and four acoustic detectors in 2017 at sites along the Missouri, Yellowstone, Little Missouri, and Powder Rivers. Across these deployments we found no call sequences that could be defined as probable or definitive for Northern Myotis.

At 157 bridges, guano samples were collected and 125 were submitted for identification. Of these 101 amplified and were identified to species or species group including one sample that was identified as Northern Myotis.

This project has led to the confirmation of presence of Northern Myotis in Montana after 38 years without detections. Through identifying where the species occurs across the nine-county listed area we were able to characterize geographic presence and habitat associations of this species. Our captures of adult testicular males, post-lactating females, and juvenile bats at multiple sites indicates that the species is a summer resident in the state. These data, combined with the historic observation of an individual hibernating, support the year-round residency of this species on the Missouri River. The proximity of the detections at Snowden Bridge in 2016 and 2017 to the historic 1800's Fort Union collection site indicates the continued persistence of this population on the Lower Missouri River.

Across the nine-county area we surveyed for Northern Myotis within two forest types. Riparian forests were typically dominated by deciduous trees such as cottonwoods, Green Ash, and Box elder among other species. Coniferous forests were typically dominated by Ponderosa Pine but sometimes included Rocky Mountain Juniper and Green Ash among other deciduous trees. All Northern Myotis were captured within riparian forest. We detected the species only once outside of riparian forests. In 2017 a guano sample collected at a bridge south of the Missouri River in short-grass prairie was identified as Northern Myotis. This bridge is roughly 7 km south-southeast of the mine where the species was originally detected and approximately 10 km south occupied forest along the Missouri River.

In-hand identification of Northern Myotis can be challenging within eastern Montana as morphologically similar species of *Myotis* species such as Long-eared Myotis or Little Brown Myotis overlap in distribution. Over the course of the project we were able to measure 12 adult Northern Myotis and characterize morphometric attributes such as the length of the forearm, ear, tragus, and hind foot. We found that length of ear relative to muzzle was the most useful characteristic for separating all similar *Myotis* species. All Northern Myotis had ears that were 3-5 mm beyond the end of the muzzle. The ear lengths of Little Brown Myotis were at or less than the length of the muzzle and Long-eared Myotis typically had ears exceeding 5 mm beyond the muzzle.

Almost all of the captures of Northern Myotis are the result of refinement of our mist net protocols. We placed nets within areas of closed canopy forest across flyways and in foraging areas. Sites were selected to be open enough to allow bats to fly through, but dense enough to provide what we assume is good habitat for Northern Myotis. Using this technique, we were also able to detect Northern Myotis at the Mortarstone Bluff and Intake Dam sites. Both locations were previously surveyed in 2016 as part of this project, but nets were placed over water rather than at upland sites.

This project confirmed the presence of Northern Myotis across the four northern-most counties in the nine-county area where the species was believed to be present, but there is still much to learn about where the species is found outside this area. Specifically, the upstream distribution on the Yellowstone and Missouri Rivers and their tributaries needs to be addressed. Furthermore, documenting whether the species is present in Ponderosa Pine forests within and outside of the listed area is also necessary. Based on these results, we recommend mist net surveys be conducted along the Milk River and tributaries of the Missouri River as these areas have the greatest potential for documenting species presence. Additionally, surveys of the Yellowstone River upstream of Miles City should continue because significant areas of riparian forest exist along this corridor. Conifer areas should still receive survey effort, but we feel that these are less of a priority as they are within the current designated range and our current survey methods have not resulted in captures. Lastly, pooled guano samples should be

collected at bridges and other potential roosts within and in proximity to the species known range to provide further information on species presence.

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Introduction

The Northern Myotis (*Myotis septentrionalis*, A.K.A Northern Long-Eared Bat) is among the least observed species found within Montana. The known global range of the species extends across central Canada through the central and eastern regions of the United States (Caceres and Barclay 2000). This species has been infrequently documented in areas adjacent to Montana's eastern and southern borders. Summer and winter records in the Black Hills of South Dakota and Wyoming are mostly limited to unpublished reports (e.g., Tigner and Aney 1993, Tigner and Aney 1994, Worthington and Bogan 1993, Tigner and Stukel 2003, Griscom and Keinath 2011). In North Dakota, two specimens were reported to have been collected in the vicinity of the border with Montana along the Missouri River near Fort Buford in 1874 and Fort Union prior to 1872 (Miller and Allen 1928, Peurach 2017). The presence of Northern Myotis in Montana was first confirmed from a single specimen collected in an abandoned coal mine (since reclaimed) near Culbertson in Richland County on 12 January 1978 (Swenson and Shanks 1979). This individual was collected and deposited in the Montana State University Zoology Museum. Despite occasional mist net and acoustic surveys across the potential range of the species in eastern Montana, this species remained undetected between the initial observation and the start of this project.

In 2015 the U.S. Fish and Wildlife Service listed the Northern Myotis as Threatened and designated the species as present in nine counties in eastern Montana with an interim special rule under the authority of section 4(d) of the Endangered Species Act of 1973 (US Fish and Wildlife Service 2015). The listing decision cited population declines within the eastern US due to White Nose Syndrome (WNS). The change in federal status created a need to understand whether the species was present in the state, its range and habitat associations to aid in management of the species and these habitats.

Recognizing Northern Myotis detected within Montana may be difficult. A unique community of *Myotis* species makes identification of all long eared *Myotis* bats more challenging for researchers in eastern Montana, eastern Wyoming, and the western portions of North and South Dakota. In these areas, Northern Myotis overlaps in range with Long-eared Myotis (*M. evotis*), and Fringed Myotis (*M. thysanodes*). Morphologically, these species are similar in size, general appearance, and have reported ear lengths of greater than 14mm (Morgan et al. 2017, Bachen et al. 2018). Additionally, acoustic detections are challenging within these areas. *Myotis* species such as long-legged Myotis (*M. volans*), Long-eared Myotis (*M. evotis*), and Western Small-footed Myotis (*M. ciliolabrum*) can have search phase calls that share attributes and are generally similar in appearance (Bachen et al. 2018).

Prior to implementation of this project, little was known about habitat associations of Northern Myotis in Montana. These data are critical for future management of the species. The single individual observed hibernating in a coal mine by Swenson and Shanks (1979) provided little information to assess habitat in the active season for the species. River breaks surround the mine adit are primarily exposed rock and badlands with sparse coverage of Rocky Mountain Juniper (*Juniperus scopulorum*), Green Ash (*Fraxinus pennsylvanicus*) and Chokecherry (*Prunus virginiana*) surrounded by prairie uplands (D. Bachen personal observation). The draws within these breaks lead to the Missouri River and areas of riparian forest dominated by cottonwoods (*Populus spp*.), Green Ash, and Box Elder (*Acer negundo*). Presumably the species used these habitat types, but from this single observation, the extent of use or even the presence during the active season was impossible to determine.

Habitat used by Northern Myotis is better documented in the Northern Great Plains east of Montana and other areas in the central US. Across the species range, Northern Myotis is generally associated with forested areas (Caceres and Barclay 2000). The species has been reported from riparian forests along

prairie rivers in Nebraska (Geluso et al. 2015) and North Dakota (Nelson et al. 2016) and in conifer dominated areas such as the Black Hills of Wyoming and South Dakota (Cryan et al. 2001) and the Bear Lodge Mountains of North East Wyoming (Geluso and Borgan 2018). Telemetry studies have identified roosts in Ponderosa Pine and Burr Oak (*Quercus macrocarpa*) in this region (Keinath and Abernethy 2016). In Badlands National Park in southern South Dakota, the species was associated with stands of cottonwood and in mixed deciduous and juniper (*Juniperous* spp.) forest (Borgan et al. 1996). In Nebraska, maternity colonies were documented within areas of deciduous forest (Stein and White 2016, Johnson and Geluso 2017). Geluso et al. (2015) surveyed across northwestern Nebraska in Ponderosa Pine (*Pinus ponderosa*) dominated uplands and lowland riparian forest dominated by Eastern Cottonwood *(P. deltoides*) and willows (*Salix* spp.), but only captured Northern Myotis in a narrow riparian area associated with large willows. Habitat associations across the species global range may help to identify habitat used in Montana. For example, riparian forest and conifer dominated upland sites are present in Montana across the nine designated counties and we targeted these areas during our survey efforts to detect the species.

Our goals for this project were to:

1. Develop protocols to identify Northern Myotis with certainty and separate similar *Myotis* species
2. Determine if Northern Myotis is present within Montana
3. If present, determine range and use detection data to infer if breeding occurs and if the species is resident or transient within Montana

Site Selection

Our area of interest was across the nine counties designated by the USFWS (Figure 1). Northern Myotis is associated with forested areas, so we chose to target both conifer-dominated uplands and deciduous forest along rivers and streams. Within these habitats, we selected sites based on accessibility, forest presence, and suitable features to survey. Within riparian forest we selected sites with waterbodies where bats could drink within or adjacent to the forest, water shallow enough to net, flyways through wooded areas, and areas of open forest that animals could forage within. In the more xeric conifer forest, we targeted water sources within or adjacent to the forests.

Methods

Between 2016 and 2019, we conducted surveys using direct capture (mist net) and acoustic methods across the nine-county designated area in eastern Montana. In addition to these surveys, this project also supported the development of genetic methods for identification of species from tissue and guano and the testing of guano samples collected at bridges during a concurrent project conducted by NHP with other partners within the area of interest. Our primary method of survey for Northern Myotis was placement of mist nets over water or across flight paths within wooded areas. We also deployed acoustic detector recorders at sites potentially used be Northern Myotis.

Mist Netting

Sites were selected based on the presence of forested areas consistent with the species' habitat associations outside of Montana (Caceres and Barclay 2000). Forested areas within this nine-county area can be classified into two general categories: 1) riparian forest often dominated by cottonwood and Green Ash located within the floodplain of large rivers such as the Yellowstone and Missouri Rivers; and 2) breaks and uplands dominated by Ponderosa Pine and Rocky Mountain Juniper, generally found south of the Yellowstone River.

We placed mist nets across features that concentrate bat activity within 3 meters of the ground or water such as water sources suitable for drinking, foraging areas, and flyways. This technique can be effective when surveying for many species of bats, including Northern Myotis. Initially we placed nets almost exclusively over water sources, which was successful in capturing bats of all species in xeric environments where water was limited. However, we struggled capture individuals of any species along large rivers where abundant water diluted bat activity and finding sites shallow enough to net was challenging. In 2017, we refined our methods and began to place nets across flyways within riparian forest along the Missouri and Yellowstone Rivers. This technique proved successful for capturing Northern Myotis and we focused our efforts on netting flyways in these habitats for the remainder of the project. As netting over water in conifer forests is successful in similar areas in adjacent states (e.g. Geluso and Bogan 2018), we continued to net these features whenever we were in this habitat.

At each site we deployed up to six nets of variable length over water and in flyways. Nets were opened at dusk and closed no earlier than 12:00 am, unless inclement weather or other factors precluded netting for a full evening. All animals captured were briefly held in cloth bags prior to processing to allow bats to defecate so that guano could be collected and used for genetic identification. Time in the bag for each animal did not exceed 0.5 hrs. For each animal, we measured ear, tragus, forearm, foot, and thumb to the nearest millimeter. We identified captured individuals to species using morphology and pelage attributes (Ormsbee 2005, Bachen et al. 2018). If an animal was suspected to be a Northern Myotis, we also took a wing biopsy (punch) for genetic confirmation of species identity as tissue returns a species identification more frequently than guano.

In July and August 2016, we conducted surveys in collaboration with MT Fish, Wildlife and Parks. A total of 23 sites were surveyed along the Little Missouri, Powder, Tongue, Yellowstone, and Missouri Rivers (Figure 1). We planned to allocate five nights to each river and met these goals on all rivers except the Little Missouri. This river corridor was surveyed for only three nights due to a lack of dense forests along much of its length in Montana.

We conducted seven nights of mist netting between August 9^{th} -17^{th} 2017. We allocated four nights to the lower Missouri and three nights to the lower Yellowstone. On the Missouri River we surveyed four separate sites (Figure 1), including the Snowden Bridge Fishing Access Site (FAS) where two Northern Myotis were captured the previous year. On the Yellowstone River we surveyed two sites: Seven Sisters FAS for a single night and Diamond Willow FAS for two nights. Two locations in Diamond Willow FAS were netted. On the first night, we netted over a side channel. On the second night, we selected sites in the forest over an irrigation ditch and within flight corridors.

For the 2018 field season we again focused our efforts on riparian forests. Between August 6^{th} and August 14^{h}, we conducted nine nights of mist netting along both the Yellowstone and Missouri Rivers. We allocated three nights to the lower Missouri and six nights to the lower Yellowstone (Figure 1). As the species had not been previously detected on the Yellowstone, we felt that allocating more effort to this area was a higher priority than extending knowledge of species presence on the Missouri River.

In 2019 we netted eight sites on and south of the Yellowstone River. We focused our efforts on under surveyed riparian habitat and areas of conifer forest. We surveyed one site for each of the Powder River, Little Missouri River, Box Elder Creek, and Yellowstone River (Figure 1). Additionally, we surveyed conifer dominated areas south of Belle Creek for one night and near the town of Knowlton off the Powder River for three nights.

Acoustic Detectors

We also deployed acoustic detectors in proximity to our mist net sites in 2016 and 2017. However, in 2018 and 2019 we did not deploy acoustic detectors because of this method's failure to detect the species at occupied sites. Detectors were deployed between 1 and 8 nights. To increase our odds of detecting the species, detectors were used to survey areas that may be suitable for Northern Myotis, but difficult to mist net. At these sites we deployed SM2Bat+ 192 kilohertz ultrasonic detectors (Wildlife Acoustics Inc., Concord, MA). following the methods in Maxell (2015), acoustic data were processed using Kaleidoscope Pro 4 software (Wildlife Acoustics Inc., Concord, MA) and analyzed using Sonobat 4.0 software (Sonobat, Arcata, CA) to determine if any Northern Myotis were detected.

Genetic Analysis of Wing Punch and Guano Samples

At the beginning of the project we worked with US Forest Service Rocky Mountain Research Station National Genomics Center for Wildlife and Fish Conservation to develop genetic tests to identify all bat species in Montana and validate morphometric identifications and guano collected at sites within the project area. We first applied these tools in 2015 during surveys conducted with partner agencies within the nine-county area and then during mist net surveys conducted for this project between 2016 and 2019. We also used these methods to test guano collected from bridge roosts as part of a partner project across the listed area in 2017.

Analysis of Guano Collected at Bridges

We also analyzed guano samples collected during bridge surveys across the nine-county area as part of a concurrent project to identify bat roosts in these features (see Bachen et al. 2019 for a description of this project). At each bridge, surveyors collected a single sample of guano deposited in a discrete area. These collection methods return only a single species per sample, thereby indicating only one of the community of species present at a bridge. However, the non-detection of a species should not be interpreted as absence of that species. All analysis was performed at the US Forest Service Rocky Mountain Research Station National Genomics Center for Wildlife and Fish Conservation.

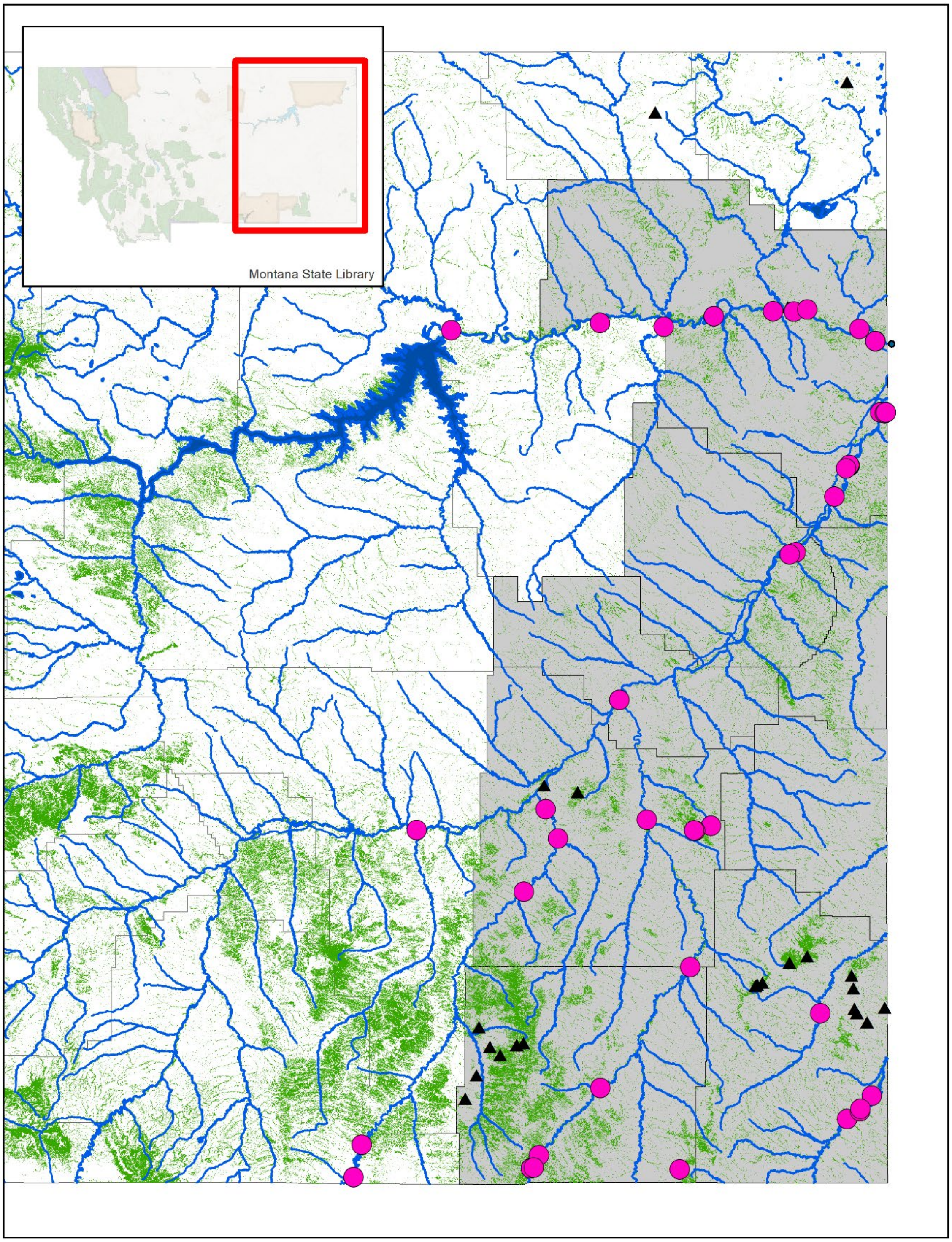

Figure 1. Sites surveyed with mist nets between 2016 and 2019 noted with pink circles. Mist net surveys conducted between 2015 and 2019 that used genetic methods but not associated with this project are shown with black triangles for perspective on survey coverage. Forested areas are shown in green and waterbodies in blue. The nine-county area where Northern Myotis may occur as designated by the USFWS is shown in grey. Note that some sites have been surveyed multiple times.

Results

Identification of Northern Myotis

We contracted with the Northern Rocky Mountain Research station to develop procedures to identify species using genetic methods. The lab was able to develop a test for species identity using two regions of mitochondrial DNA (*cytochrome oxidase I* and *cytochrome b*). Ultimately, this test is effective for all Montana bat species except for Long-eared Myotis and Fringed Myotis which are too genetically similar to differentiate at these sites (K. Pilgrim, pers comm.). Using these tests, we were able to confirm the identification of all Northern Myotis captured. Additionally, we were able to confirm two individuals that we believed to be Northern Myotis but were not confident in our determination based on morphometrics. Across the project we only had one individual that we suspected might have been a Northern Myotis but was identified as another species (Little Brown Myotis) using this method.

We are confident of the species identifications for all *Myotis* bats captured during the project using genetic methods except for Long-eared/ Fringed Myotis which can be reliably separated morphologically (Ormsbee 2005, Bachen et al. 2018). We were able to determine the effectiveness of published keys for discriminating between species of *Myotis* and develop criteria to effectively identify Northern Myotis in the Northern Great Plains Region. Over the course of the project, we measured 12 adult Northern Myotis and characterized morphometric attributes such as the length of the forearm, ear, tragus, and hind foot. As length of ear past nose is commonly suggested to differentiate Northern Myotis and other *Myotis* species (e.g. Morgan et al. 2017), we also recorded this measurement. When compared with data for Long-eared Myotis and Little Brown Myotis, Northern Myotis have ear lengths intermediate to both species. The typical ear length for Northern Myotis range between 14 and 17mm, but most commonly measure 15 mm. This results in ear length between 3 and 5 mm extended beyond the tip of the nose. Northern Myotis also appear to be smaller on average than these other species. See Appendix A for a dichotomous key and detailed description of morphological differences between the species of long-eared *Myotis* known to co-occur with Northern Myotis in the project area.

Mist Netting

In 2016, we targeted deciduous riparian woodlands and captured then genetically confirmed three adult Northern Myotis at two sites on the Missouri River. These capture sites were near the historic records within Montana and North Dakota (Figure 2). At the Snowden Bridge Fishing Access Site (FAS), we captured two females that appeared to have bred that year. Upstream at the Culbertson FAS, we captured an adult reproductive male. The Culbertson FAS record is about 5 km northeast of the 1978 record from an abandoned coal mine. The Snowden Bridge FAS captures are less than 3 km from Fort Union. Due to the proximity of potential hibernacula and swarming sites to the testicular male captured in the Culbertson area, it is possible that this species could be breeding and over-wintering in Montana.

During 2016 efforts we also captured 132 individuals representing seven additional species including Hoary Bat (*Lasiurus cinereus*), Eastern Red Bat (*L. borealis*), Silver-haired Bat (*Lasionycteris noctivagans*), Big Brown Bat (*Eptesicus fuscus*), Little Brown Myotis, Long-eared Myotis, and Western Small-Footed Myotis. Of these species captured, Hoary Bat, Eastern Red Bat, and Little Brown Myotis are State Species of Concern while Silver-haired Bat is a Potential Species of Concern.

We captured 10 Northern Myotis at two sites during 2017 surveys (Figure 2). At the Snowden Bridge FAS, we captured six individuals, two males and four females. We captured an additional four juvenile males on a BLM parcel south of Culbertson near the mine where this species was first detected in

Montana. All animals were captured in nets set within riparian forest across potential flyways. Individuals all had ears between 14 and 16 mm (Appendix A).

In addition to Northern Myotis, we also captured 30 individuals representing five additional species: Eastern Red Bat, Silver-haired Bat, Townsend's Big-eared Bat (*Corynorhinus townsendii*), Big Brown Bat, and Little Brown Myotis. Townsend's Big-eared Bat and Little Brown Myotis are listed as state of Montana Species of Concern and the Silver-haired Bat is listed as a Potential Species of Concern. The captures of the Eastern Red Bat are particularly notable as this species had been captured in-hand fewer than 10 times within the state. At the Diamond Willow FAS, we captured seven individuals in a single night.

In August 2018 we conducted nine nights of mist netting along both the Yellowstone and Missouri Rivers. During this effort we captured six Northern Myotis at three sites (Figure 2). All animals were captured in nets set within riparian forest across flyways. Individuals all had ear lengths between 14 and 16 mm (Appendix A). Initially, a single Little Brown Myotis captured at the Mortarstone Bluff site was misidetified as a Northern Myotis. This individual had an ear length of 14 mm. However, there was some degree of uncertainty in species identification based on the general "gestalt" of the animal and genetic analysis confirmed that it was a Little Brown Myotis. In addition to the Northern Myotis, we captured 21 individuals representing six species including Eastern Red Bat, Silver-haired Bat, Townsends Big-eared Bat, Little Brown Myotis, Long-eared Myotis, and Western Small-footed Myotis.

During 2019 we netted eight sites along and south of the Yellowstone River in both riparian forest and Ponderosa pine dominated uplands. Across these surveys, we captured 13 bats representing six species including Silver-haired Bat, Townsend's Big-eared Bat, Long-eared Myotis, Fringed Myotis, Western Small-footed Myotis, and Long-legged Myotis. We did not capture any individuals suspected or confirmed to be Northern Myotis.

Exact capture location and species detection data have been entered into the Montana Natural Heritage Program databases. These materials are available through our online tools and reports, and directly by request to the Montana Natural Heritage Program.

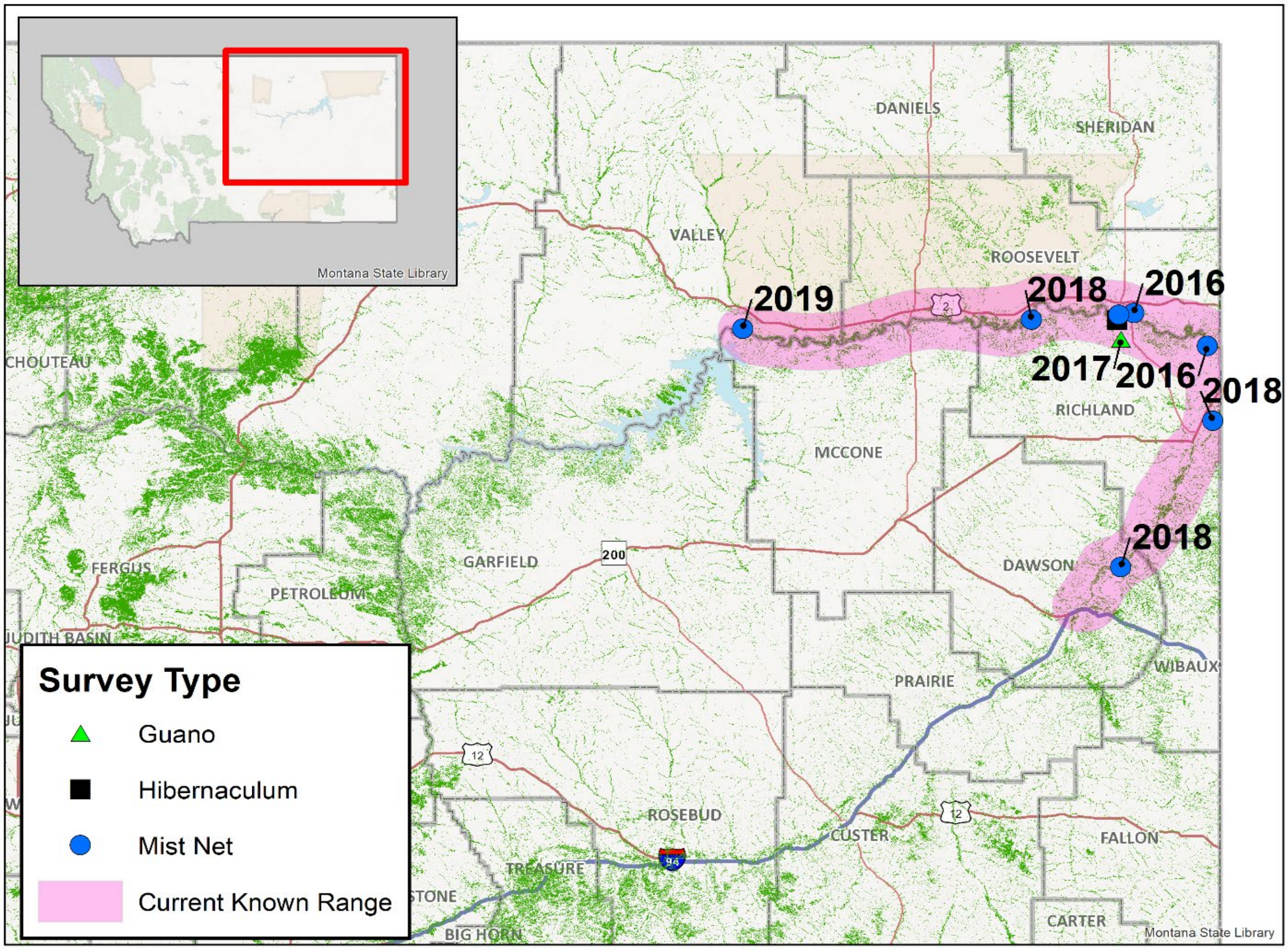

Figure 2. Past and current occurrences of Northern Myotis with year of detection and detection type noted. All occurrences were discovered during this project. Exceptions to this are the observation of an overwintering bat in a coal mine in 1978 and the capture of the species near Fort Peck Dam in 2019. Forested areas of all types are shaded in green. Note the mine where the individual was observed overwintering in 1978 has since been reclaimed and no longer has the capacity to serve as a hibernaculum.

Acoustic Detectors

We deployed seven acoustic detectors in 2016 and four acoustic detectors in 2017 at sites along the Missouri, Yellowstone, Little Missouri, and Powder Rivers. Across these deployments we found no call sequences that could be defined as probable or definitive for Northern Myotis.

Bridge Surveys

At 157 bridges, guano samples were collected and 125 were submitted for identification. Of these 101 amplified and were identified to species or species group. Across the area 5 species were identified (Figure 3), Big Brown Bat, Little Brown Myotis, Western Small-footed Myotis, Northern Myotis, and Long-eared/ Fringed Myotis which cannot be differentiated with current methods.

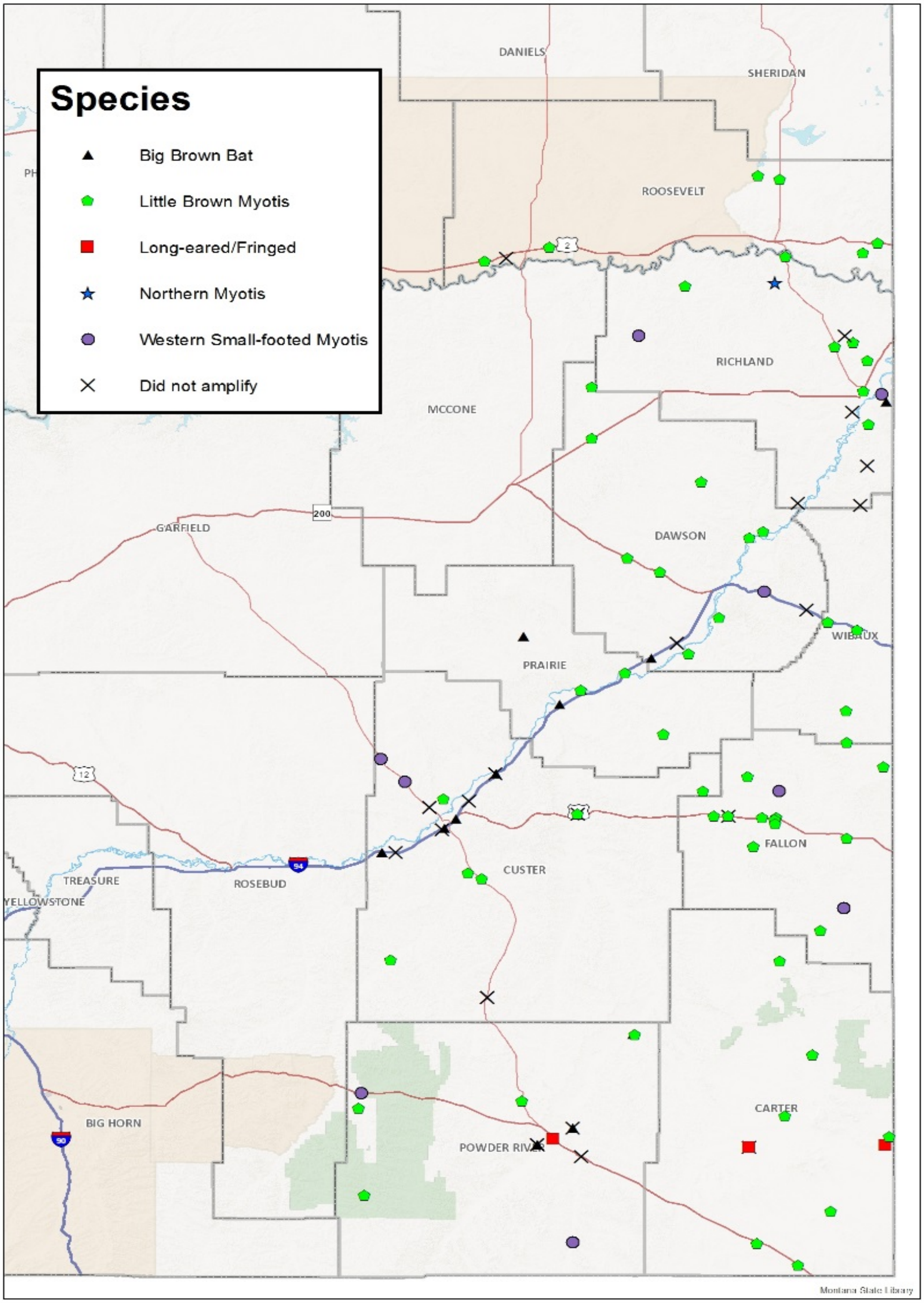

Figure 3. Species identified at bridges through genetic analysis of guano samples. Across the area, five species were detected, including the Northern Myotis at a single bridge in Richland County.

Discussion

This project has led to the confirmation of presence of Northern Myotis in Montana after 38 years without detections. Through identifying where the species occurs across the nine-county listed area we were able to identify areas where the species is present and habitat associations of this species. Our captures of adult testicular males, post-lactating females, and juvenile bats at multiple sites indicates that the species is a summer resident in the state. These data combined with the historic observation of an individual hibernating (Swenson and Shanks 1979) support the year-round residency of this species on the Missouri River. The proximity of the detections at Snowden Bridge in 2016 and 2017 to the historic 1800's Fort Union collection site indicates the continued persistence of this population on the Lower Missouri River.

Within the past few years, White-Nose Syndrome or the causal agent *Pd* has been detected in states bordering Montana (White-nose syndrome Occurrence Map – by year 2019). That *Pd* has been detected in the Missouri River Valley in North Dakota is of particular concern as all known occurrences of Northern Myotis in Montana are along this river and its tributaries. By beginning to characterize the species distribution and habitat associations in Montana before populations are impacted by the disease, we have established baseline information to aid in assessing impacts of the disease on this species.

Across the nine-county area we surveyed for Northern Myotis within two forest types. Riparian forests were typically dominated by deciduous trees such as cottonwoods, Green Ash, and Box elder among other species. Coniferous forests were typically dominated by Ponderosa Pine but sometimes included Rocky Mountain Juniper and Green Ash among other deciduous trees. All Northern Myotis were captured within riparian forest. Across sites where the species was present, we observed a strong correlation with Green Ash. To a lesser extent we also found the species associated with stands of younger cottonwood and willows similar to the forest composition observed by Geluso et al. (2015) in Nebraska. The species may use deciduous forests with different characteristics than those observed during this project and lack of detections in other forest types could be due to our survey techniques.

We detected the species only once outside of riparian forests. In 2017 a guano sample collected at a bridge south of the Missouri River in short-grass prairie was identified as Northern Myotis. This bridge is roughly 7 km south-southeast of the mine where the species was originally detected and approximately 10 km south occupied forest along the Missouri River. It is difficult to determine why the species was present at this bridge, but grassland is atypical for the species in Montana and across its global range (Caceres and Barclay 2000).

Species Detection

Almost all of the captures of Northern Myotis are the result of refinement of our mist net protocols. For most projects in Montana, mist nets are typically placed over water sources (Figure 4a) as these features concentrate bats near ground level when they drink and can be captured in nets. As all species present in an area will need to drink every night, netting waterbodies is often the best way to maximize both the number of captured individuals as well as species diversity. In our experience, netting across water becomes less effective as the amount of water on the landscape increases. If bats can drink at water sources across an area, the relative importance of a site where nets are placed is reduced resulting in fewer animals captured. This can be particularly problematic for species that do not typically forage over water such as Northern Myotis, as they forage in forested areas (Caceres and Barclay 2000) which limits time near water and capture opportunity. This appears to be one of the reasons that surveys along the Missouri and Yellowstone Rivers using mist nets set over water have resulted in few captures.

Figure 4.Examples of mist net placements, over water (a) and within riparian forest (b). In 2016 and 2017 we found that sets over water were less effective for capture of Northern Myotis (1 capture) than sets in flight corridors in wooded areas (12 captures).

We were able to increase the likelihood of captures of Northern Myotis in 2017 because we refined our mist net protocols. We placed nets within areas of closed canopy forest across flyways and in foraging areas. Sites were selected to be open enough to allow bats to fly through, but dense enough to provide what we assume is good habitat for Northern Myotis (Figure 4b). When possible, we also targeted stands where the canopy height was at or within a meter of the top of our nets to reduce the ability of animals to avoid capture. At the Snowden Bridge FAS, we increased captures from two and zero bats during two nights in 2016 to six bats in 2017. We believe the increase in captured individuals is a direct result of changes in net placement between years. Using this technique, we were also able to detect Northern Myotis at the Mortarstone Bluff and Intake Dam sites. Both locations were previously surveyed in 2016 as part of this project, but nets were placed over water rather than at upland sites and Northern Myotis was not detected.

Focusing on flight corridors and foraging areas within deciduous forests made detection of the species possible in areas with abundant water. However, we continued to set nets over water in xeric upland areas dominated by conifers. We chose to continue using these methods for two reasons: First, these methods are used successfully in Ponderosa Pine forests in states adjacent to Montana (Griscom and Keinath 2011, Geluso et al. 2017). Secondly, pine forests typically have higher canopies, less distinct flyways, and cover a greater area. These limitations make nets placed in these areas ineffective at capturing all bat species. In theory, if Northern Myotis is present in an area and water is limited, bats must drink from one of the available water bodies. This would make them more vulnerable to nets set over these water sources and we feel that this continues to be a viable method for detecting Northern Myotis in these habitats.

The confirmation of Northern Myotis presence in Ponderosa Pine-dominated conifer forests across central and southeastern Montana continues to be problematic. In combination with USFWS funded efforts, the Custer-Gallatin National Forest in partnership with NHP has put significant effort into characterizing bat communities across the Ashland and Sioux Districts in southeast Montana. To-date good coverage of mist net surveys exists across much of the Ashland District and within the Sioux District in Montana. However, some areas of the Sioux District in South Dakota including the East and West Short Pines remain under-surveyed. Across these surveys, no animals have been captured that have been confirmed as Northern Myotis. While this does not prove absence, consistent surveys without detection of the species suggests that if the species is present it is extremely difficult to detect with methods proven effective in similar habitat (e.g. Geluso and Bogan 2018). Other areas of pine forest should also receive more survey effort as few surveys have been conducted with these areas. Particularly, the pine breaks east of Glendive and in the vicinity of Belle Creek are under-surveyed and are close to known populations along the Yellowstone River and Bear Lodge Mountains, respectively.

Through genetic identification of guano samples collected at bridges we were able to add one additional occurrence of the Northern Myotis at a bridge in Richland County. This observation extended the known range of the species away from riparian forest along the Missouri River into upland areas. The area surrounding the bridge has few if any trees, which is drastically different than the habitat where the species has been observed elsewhere in the state. The bridge is within 6.8 km of the 1978 observation of an individual hibernating in a coal mine. Furthermore, the area surrounding this decommissioned mine has several other adits which may serve as hibernaculum. It is possible that the guano was deposited by an animal traveling to or from hibernacula within the general area, although both the mines and riparian forest are north of the bridge. It may also be plausible that the animal was migrating or dispersing to an area further to the south.

Finding guano from a Northern Myotis at a bridge also confirms the species use of these structures and validates an additional tool for survey of this species. As our methods did not allow for direct observation of how the animal used the bridge, we cannot confirm if it was a day or night roost or why the animal was using the structure. Furthermore, our sampling protocol was not adequate to confirm absence at any bridge it is impossible to quantify how common or rare use of these structures is. In the future, bridge surveys should employ genetic methods that can return a community of species from pooled samples of guano collected from roosts across the bridge. This will provide a more complete assessment of which species of bat are commonly use bridges and may help identify additional areas and habitats where Northern Myotis is found.

Identification of Northern Myotis

In-hand identification of Northern Myotis can be challenging within eastern Montana as morphologically similar species of *Myotis* species such as Long-eared Myotis or Little Brown Myotis overlap in distribution (Bachen et al. 2018). Over the course of the project we were able to measure 12 adult Northern Myotis and characterize morphometric attributes such as the length of the forearm, ear, tragus, and hind foot. As length of ear past nose is commonly suggested to differentiate this and other *Myotis* species (Caceres and Barclay 2000, Morgan et al. 2017), we also recorded this measurement. Northern Myotis had ear lengths intermediate to both species and typically between 14 and 17mm with the most commonly measured length of 15 mm. In contrast, Little Brown Myotis typically had ears that were 14 mm or less and rarely 15 mm in length. Long-eared Myotis typically had ears exceeding 15mm in length and most individuals had ears that were at least 17mm. We found that length of ear relative to muzzle was the most useful characteristic for separating all similar *Myotis* species. All Northern Myotis had ears that were 3-5 mm beyond the end of the muzzle. The ear lengths of Little Brown Myotis were at or less than the length of the muzzle and Long-eared Myotis typically had ears exceeding 5 mm beyond the muzzle. Pelage color of Northern Myotis was variable, but all individuals had membranes that were brown without much contrast to pelage similar to Little Brown Myotis. Long-eared Myotis had contrasting dark membranes and light-colored fur. Although morphometric attributes will never replace genetic confirmation due to overlap between species, Northern Myotis can typically be separated from similar species by length of ear beyond muzzle and color of pelage. See Appendix A for criteria useful for identifying Northern Myotis within our area of interest.

Future Work

This project confirmed the presence of Northern Myotis across the four northern-most counties in the nine-county area where the species was believed to be present, but there is still much to learn about where the species is found outside this area. Specifically, the upstream distribution on the Yellowstone and Missouri Rivers and their tributaries needs to be addressed. Furthermore, documenting whether the species is present in Ponderosa Pine forests within and outside of the listed area is also necessary. Recently other work has detected Northern Myotis below the Fort Peck Reservoir, extending the known range along the Missouri River upstream from the Mortarstone Bluffs site. We updated the predicted habitat suitability model to include these observations. In addition to areas known to be occupied, the model highlighted habitat along the Milk River upstream to the Malta area in Phillips County and tributaries of the Missouri River that extend into northern Roosevelt, Sheridan, and Daniels counties (Appendix B). Several small areas along and upstream of Fort Peck Reservoir on the Missouri River are highlighted as suitable habitat. Presumably riparian forest extended upstream of the dam site prior to its construction in 1940, which may have been occupied by the species. The impact of the flooding of this habitat and subsequent changes in the distribution of Northern Myotis are unknown. Whether the species can be found in these forested areas highlighted should be explored in the future. The model does not show large areas of suitable habitat on the Yellowstone River upstream current known range. Nevertheless, continued survey efforts upstream of Miles City will help provide evidence of species presence or support for species absence.

Based on these results, we recommend mist net surveys be conducted along the Milk River and tributaries of the Missouri River as these areas have the greatest potential for extending the current known range. Additionally, surveys of the Yellowstone River upstream of Miles City should continue because significant areas of riparian forest exist along this corridor. Conifer areas should still receive

survey effort, but we feel that these are less of a priority as they are within the current designated range and our current survey methods have not resulted in captures. Lastly, pooled guano samples should be collected at bridges and other potential roosts within and in proximity to the species known range to provide further information on species presence.

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Appendix A

Identification of Northern Myotis

In eastern Montana, Northern Myotis has a sympatric distribution with three other *Myotis* species that appear similar and may be difficult to distinguish from this species including Long-eared Myotis, Fringe Myotis, and Little Brown Myotis. This community is relatively unique as Long-eared and Fringed Myotis are typically found in the western US. As such, many resources for identification of long-eared *Myotis* species lack adequate detail or have vague criteria for separate Northern Myotis from other similar species.

To address the need to establish identification criteria for Northern Myotis, we have compiled morphological data from captures across this sympatric area to create a more parsimonious aid in identification of this species. From the NHP capture database we queried all records east of -106.5 longitude to account for any geographic variability in widely distributed species like Little Brown Myotis. We also limited these data to individuals reported as adults but did not separate males from females. In total we analyzed data from 78 Long-eared Myotis, 129 Little Brown Myotis, 12 Northern Myotis, and 4 Fringed Myotis. Although Fringed Myotis might be confused with Northern Myotis based on ear length we did not include them in the figures as they can be separated from other *Myotis* species in the region based the presence of a robust fringe of hair on their uropatagium.

Based on these data, on average species occupy their own space when size and ear length are considered. However, some individuals of other *Myotis* species have morphological features that overlap with observed measurements for Northern Myotis. Therefore, all Northern Myotis and any other *Myotis* species with a morphology that is indeterminant between species should have the initial identification confirmed using genetic methods applied to guano or a tissue biopsy.

Key for Identification of Northern Myotis in the Northwest Great Plains

1a. Obvious fringe of stiff bristles present on uropatagium. **Fringed Myotis** (*Myotis thysanodes,* MYTH)
1b. Uropatagium lacks hair/ bristles, or if hair is present it is sparse and fine. (2)

2a. Membranes are dark brown/ black and in contrast to light fur. Ears typically 16mm or greater. When ears pressed forward they exceed the end of the muzzle by > 5mm. **Long-eared Myotis** (*Myotis evotis*, MYEV)
2b. Not as above. Pelage and membranes are drab and show less contrast ears <17mm (3)

3a. Ears between 14 and 17 mm, often 15-16mm. When ears pressed forward they exceed the muzzle by 3-5 mm. Adult forearm is between 33 and 37mm and often around 35mm. Pink skin is readily apparent on side of muzzle and around eyes. **Northern Myotis** (*Myotis septentrion*alis, MYSE)
3b. Ears almost always < 14mm and do not extend or barley extend past the end of the muzzle when pressed forward. Pelage color variable but typically membranes are brown and do not contrast with pelage. Forearm typically between 35 and 39mm and often around 37mm. In rare instances individuals have ear measurements of 15 and 16 mm. **Little Brown Bat** (*Myotis lucifugus*, MYLU)

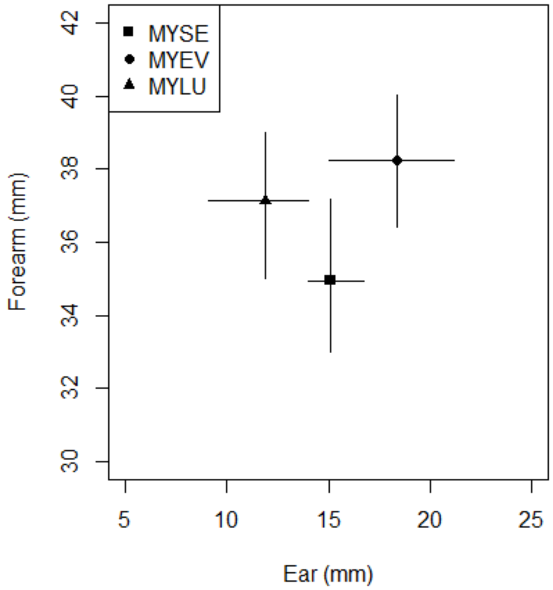


Figure A1. A comparison of ear and forearm length for Northern Myotis (MYSE), Long-eared Myotis (MYEV), and Little Brown Myotis (MYLU). Points are average, measurements of adult animals of both sexes. Bars show the 90th percentile for each measurement.

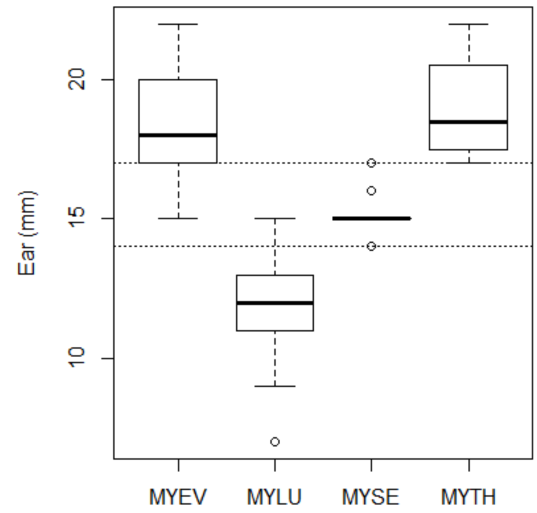
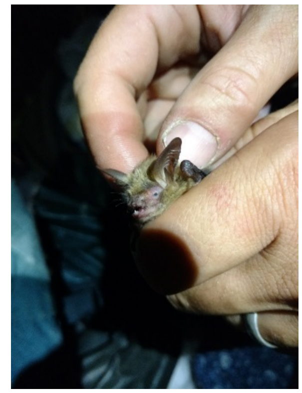


Figure A2. The distribution of ear size across four species of Myotis bats. The box and whisker plots show the 5th, 25th,50th, 75th, and 95th percentiles for each species. The upper and lower bounds of the Northern Myotis measurements (14 and 17mm) have been highlighted with dashed lines.

Figure A3. A comparison of the contrast between pelage and membrane color for Northern Myotis (left) and Long-eared Myotis (right). Note the pink skin visible around the eyes and on the muzzle on the Northern Myotis and high degree of contrast with the Long-eared Myotis. Photo was taken along the Missouri River in riparian forest.

Appendix B
Northern Myotis (*Myotis septentrionalis*)
Predicted Suitable Habitat Modeling

Distribution Status: Resident Year Round
State Rank: S2 (Species of Concern)
Global Rank: G1G2



Modeling Overview

Created by: Braden Burkholder
Creation Date: October 14, 2019
Evaluator: Braden Burkholder
Evaluation Date: October 16, 2019

Inductive Model Goal: To predict the distribution and relative suitability of general year-round habitat for Northern Myotis at large spatial scales across its presumed range in Montana.
Inductive Model Performance: Despite small sample size due to difficulty in detecting this species, the model appears to do a reasonable job of highlighting areas and habitats consistent with detections across the current known distribution of Northern Myotis. However, sampling methods are most effective in riparian forest, so the suitability of other habitats and areas used by the species may be misclassified due to lack of detections rather than true absence. As such, areas classified as unsuitable may still be used by this species in the active season or to overwinter. Furthermore, we have expanded the model to areas outside of the known range to inform future survey efforts but any predation outside of the known range should be interpreted with caution due to model uncertainty and various biotic and abiotic factors. Evaluation metrics indicate the model output has high variance and moderate model fit given the small amount of data available for modeling. The delineation of habitat suitability classes is supported by the data despite low data volume.
Deductive Model Goal: To represent the ecological systems commonly and occasionally associated with Northern Myotis year-round, across its presumed range in Montana.
Deductive Model Performance: Ecological systems that Northern Myotis is commonly and occasionally associated with generally represent what we know about the amount of suitable active season habitat across the species' known active season range in Montana

Suggested Citation: Montana Natural Heritage Program. 2019. Northern Myotis (*Myotis septentrionalis*) predicted suitable habitat models created on October 14, 2019. Montana Natural Heritage Program, Helena, MT. 40 pp.

Montana Field Guide Species Account: http://fieldguide.mt.gov/speciesDetail.aspx?elcode=AMACC01150

Inductive Modeling

Model Limitations and Suggested Uses

This model is based on statewide biotic and abiotic layers originally mapped at a variety of spatial scales and standardized to 90×90 meter raster pixels. The spatial accuracy of the training and testing data are varied (typically 20-400 meters) and may result in additional statistical noise in the model. As a result, model outputs may not be appropriate for use on smaller areas or at fine spatial scales. Model outputs should not typically be used for planning efforts on land areas smaller than one quarter of a public land survey system (PLSS) section (<64 hectares) and model outputs for some species may only be appropriate for broader regional level planning efforts. Model outputs should not be used in place of on-the-ground surveys for species, and wildlife and land management agency biologists should be consulted about the value of using model output to guide habitat management decisions for regional planning efforts or local projects. See Suggested Contacts for Natural Resource Agencies attached to this document.

Inductive Model Methods

Modeling Process

Presence-only data were obtained from Montana Natural Heritage Program Databases, which serve as a clearinghouse for animal and plant observation data in Montana. These data were then filtered to ensure spatial and temporal accuracy and to reduce spatial auto-correlation (summarized in Table 1). The spatial extent of this model was limited to the presumed geographic range of the species, by season when applicable, in order to accurately assess potentially available habitat.

We then used these data and 19 statewide biotic and abiotic layers (Table 2) to construct the model using a maximum entropy algorithm employed in the modeling program Maxent (Phillips et al. 2006, Ecological Modeling 190:231-259). Entropy maximization modeling functions by calculating constraints and then applying the constraints to estimate a predicted distribution. The mean and variance of the environmental variables at the training data locations are used to estimate the constraint distributions. Maxent requires that the final predicted distribution fulfills these constraints. Maxent avoids overfitting models to the training data by "regularizing" or relaxing the constraints so that modeled distributions only have to be close to, rather than exactly equal to, the constraint distributions (Elith et al. 2011, Diversity and Distributions 17:43-57).

Maxent fits a model by assuming the predicted distribution is perfectly uniform in geographic space and moves away from this distribution only to the extent that it is forced to by the constraints. Constrained by training data, Maxent successively modifies the coefficients for each environmental variable via random walk, accepting the modified coefficient if it increases the gain. Gain is a measure of the closeness of the model concentration around the presence samples that is similar to goodness of fit in generalized linear models. The random walk of coefficients continues until either the increase in the gain falls below a set threshold or a set maximum number of iterations are performed. The gain value at the end of a model run indicates the likelihood of suitability of the presence samples relative to the likelihood for random background points. The overall gain associated with individual environmental variables can be used as a measure of the relative importance of each variable (Merow et al. 2013, Ecography 36:1058-1069).

We employed a k-folds cross validation methodology, in this case using ten folds for model training and validation (Elith et al. 2011). Each fold consists of 90% of the data designated for training and 10% of the data reserved for testing. Each record is used for training nine times and testing once. Ten models are estimated and averaged to produce the final model presented here.

Model Outputs and Evaluation

The initial model output is a spatial dataset of continuous logistic values that ranges from 0-1 with lower values representing areas predicted to be less suitable habitat and higher values representing areas predicted to be more suitable habitat (Figures 3 & 5-7). The standard deviation in the model output across the averaged models is also calculated and plotted as a map to examine spatial variance of model output (Figure 4). If enough observations were available to train and evaluate the models, the continuous output is reclassified into suitability classes - unsuitable, low suitability, moderate suitability, and high suitability (Figures 8 & 9). Thresholds for defining suitability classes are presented and described below (Table 4).

In addition to the map of spatial variance in model output, we also evaluated the output of the Maxent model with absolute validation index (AVI) (Hirzel et al. 2006, Ecological Modelling 199:142-152) and deviance (Phillips and Dudik 2008, Ecography 31: 161-175). These metrics are described below in the results (Table 5). Area under the curve (AUC) values are also displayed for reference, but are not used for evaluation (Lobo et al. 2008, Global Ecology and Biogeography 17:145-151). Finally, a deviance value was calculated for each test data observation as a measure of how well model output matched the location of test observations and this was plotted with larger symbols indicating larger deviance (Figure 6). In theory, everywhere a test observation was located, the logistic value should have been 1.0. The deviance value for each test observation is calculated as -2 times the natural log of the associated logistic output value.

Table 1: Model Data Selection Criteria and Summary

Location Data Source	Montana Natural Heritage Program Databases
Total Number of Records	10
Location Data Selection Rule 1	Records with <= 1000 meters of locational uncertainty
Number of Locations Meeting Selection Rule 1	10
Location Data Selection Rule 2	No overlap in locations within 400 meters in order to avoid spatial autocorrelation
Observation Records used in Model (Locations Meeting Selection Rules 1 & 2)	8
Season Modeled	Year-round
Number of Model Background Locations	40,084

Table 2: Environmental Layer Information

Layer	Identifier	Original Scale	Description
Land Cover	catesys	30m	Categorical. Landcover classes (25) from the 2016 Montana Spatial Data Infrastructure Land Cover Framework; Level 2 classes used with a few minor changes including removal of linear and point features: Alpine Grassland and Shrubland, Alpine Sparse and Barren, Conifer-dominated Forest and Woodland (mesic-wet), Conifer-dominated Forest and Woodland (xeric-mesic), Deciduous dominated forest and woodland, Mixed deciduous/coniferous forest and woodland, Lowland/Prairie Grassland, Montane Grassland, Agriculture, Introduced Vegetation/Pasture/Hay, Developed, Mining and Resource Extraction, Wetland or Marsh, Floodplain and Riparian, Open Water, Wet meadow, Harvested Forest, Insect-Killed Forest, Introduced Vegetation, Recently burned, Deciduous Shrubland, Sagebrush Steppe or Desert Scrub, Sagebrush or Saltbush Shrubland, Bluff/Badland/Dune, Cliff/Canyon/Talus http://geoinfo.msl.mt.gov/msdi/land_use_land_cover
Geology	catgeol	vector	Categorical. Basic rock classes (5) as defined by USGS (plus water for large water bodies): Sedimentary, Unconsolidated, Metamorphic, Plutonic, and Volcanic. https://mrdata.usgs.gov/geology/state/state.php?state=MT
Soil Order	catsoilord	Vector	Categorical. Major soil orders (7) as defined by USDA based on STATSGO2 general statewide soil maps, along with non-soil (Rock, Water) classifications: Entisols, Inceptisols, Aridisols, Mollisols, Alfisols, Andisols, and Vertisols. http://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx
Soil Regime	catsoiltemp	vector	Categorical. Soil Moisture and Temperature regimes (11) classification pairs as defined by USDA (plus water): Cryic/Udic, Cryic/Udic Ustic, Cryic/Typic Ustic, Cryic/Aridic Ustic, Cryic/Typic Xeric, Frigid/Aquic, Frigid/Udic, Frigid/Typic Ustic, Frigid/Aridic Ustic, Frigid/Typic Xeric, Mesic/Ustic Aridic. http://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx
Elevation	contelev	≈10m	Continuous. Elevation in meters above mean sea level. https://www.sciencebase.gov/catalog/item/4f70aa9fe4b058caae3f8de5
Aspect (East-West)	contewasp	≈10m	Continuous. Aspect of slopes, ranging from 1 (east) to -1 (west). https://www.sciencebase.gov/catalog/item/4f70aa9fe4b058caae3f8de5
Aspect (North-South)	contnsasp	≈10m	Continuous. Aspect of slopes, ranging from 1 (north) to -1 (south). https://www.sciencebase.gov/catalog/item/4f70aa9fe4b058caae3f8de5
Slope	contslope	≈10m	Continuous. Percent slope (x100) of landscape. https://www.sciencebase.gov/catalog/item/4f70aa9fe4b058caae3f8de5
Ruggedness	contvrm	≈10m	Continuous. Vector ruggedness measure (0 to 1). https://www.sciencebase.gov/catalog/item/4f70aa9fe4b058caae3f8de5
Summer Solar Radiation	contsumrad	≈10m	Continuous. Solar radiation (WH/m^2) for the day of the summer solstice. https://www.sciencebase.gov/catalog/item/4f70aa9fe4b058caae3f8de5
Winter Solar Radiation	contwinrad	≈10m	Continuous. Solar radiation (WH/m^2) for the day of the winter solstice. https://www.sciencebase.gov/catalog/item/4f70aa9fe4b058caae3f8de5
Annual NDVI	contndvi	900m	Continuous. Normalized Difference Vegetation as a measure of yearly mean greenness from the MODIS Terra satellite. ftp://mco.cfc.umt.edu/ndvi/terra/yearly_normals/
Annual Precipitation	contprecip	≈800m	Continuous. Average annual precipitation (mm) for 1981-2010. http://www.prism.oregonstate.edu/normals/
Percent Winter Precipitation	contwinpcp	≈800m	Continuous. Average percent (0 to 1) of the total annual precipitation that occurs during winter (Nov-Apr) for 1981-2010. http://www.prism.oregonstate.edu/normals/
Max Summer Temp	conttmax	800m	Continuous. Average maximum temperature (°C) in July for 1981-2010. ftp://mco.cfc.umt.edu/tmax/monthly_normals/
Min Winter Temp	conttmin	800m	Continuous. Average minimum temperature (°C) in January for 1981-2010. ftp://mco.cfc.umt.edu/tmin/monthly_normals/
Degree Days	contddays	800m	Continuous. Average annual total of degree days (°F) above 32°F for 1981-2010. http://services.cfc.umt.edu/arcgis/rest/services/Atlas/Temperature_CropDegreeDays32F/ImageServer
Distance to Stream	contstrmed	vector	Continuous. Distance to major streams in meters, based on major streams identified in TIGER files or USGS topographic maps (Stream_Lake_1993 dataset). http://ftp.geoinfo.msl.mt.gov/Data/Spatial/NonMSDI/Shapefiles/
Distance to Forest Cover	contfrsted	30m	Continuous. Distance to any forest land cover type in meters. http://geoinfo.msl.mt.gov/msdi/land_use_land_cover

Inductive Model Results

Table 3: Environmental Layer Contributions to Model Fit

Layer ID	Percent Contribution[a]	Layer ID	Percent Contribution[a]
catgeol	23.4%	contstrmed	0.7%
catsoiltemp	17.3%	contsumrad	0.7%
catesys	14.1%	contwinpcp	0.3%
catsoilord	13.8%	contndvi	0.1%
conttmin	11.4%	contprecip	0.1%
contelev	9.1%	contewasp	0.0%
contfrsted	4.8%	contvrm	0.0%
contnsasp	2.8%	contslope	0.0%
contwinrad	1.2%	contddays	0.0%

[a] Relative contributions of the layers to the model based on changes in fit (gain) during iterations of the training algorithm.

Table 4: Habitat Suitability Thresholds

Measure	Value
Low Logistic Threshold[a]	0.002
Moderate Logistic Threshold[b]	0.072
Optimal Logistic Threshold[c]	0.154
Area of entire modeled range (percent of Montana)	254,221.26 km^2 (66.8%)
Total area of predicted suitable habitat within modeled range	9,947.3 km^2
Area of predicted low suitability habitat within modeled range	7,912.1 km^2
Area of moderate suitability habitat within modeled range	840.5 km^2
Area of predicted optimal habitat within modeled range	1,194.7 km^2

[a] The logistic threshold between unsuitable and low suitability as determined by Maxent which balances data omission error with minimizing predicted suitable area. This is a conservative threshold that should encompass nearly all potentially suitable habitat for a species.
[b] The logistic threshold value where the percentage of test observations above the threshold is what would be expected if the observations were randomly distributed across logistic value classes (Hirzel et al. 2006). This is equivalent to a null model. When sample sizes are small, it may be undetermined.
[c] The logistic threshold where the percentage of test observations above the threshold is 10 times higher than would be expected if the observations were randomly distributed across logistic value classes. When sample sizes are small, it may be undetermined.

Table 5: Evaluation Metrics

Metric	Value
Low AVI[a]	87.5%
Moderate AVI[a]	75.0%
Optimal AVI[a]	75.0%
Average Testing Deviance ($\bar{x} \pm sd$)[b]	3.117 ± 4.591
Training AUC[c]	0.999
Test AUC[d]	0.997

[a] Absolute Validation Index: The proportion of test locations that fall above the low, moderate, or optimal logistic threshold.
[b] A measure of how well model output matched the location of test observations. In theory, everywhere a test location was located, the logistic value should have been 1.0. The deviance value for each test location is calculated as -2 times the natural log of the associated logistic output value. For example, the equivalent deviance values for the low, moderate and optimal logistic thresholds of this model would be 12.332, 5.273 and 3.740, respectively. Deviances for individual test locations are plotted in Figure 6.
[c] The area under a curve obtained by plotting the true positive rate against 1 minus the false positive rate for model training observations (averaged over 10 folds). Values range from 0 to 1 with a random or null model performing at a value of 0.5.
[d] The same metric described in c, but calculated for test observations.

Figure 1. Jackknife assessment of contribution by individual environmental layers to training gain.

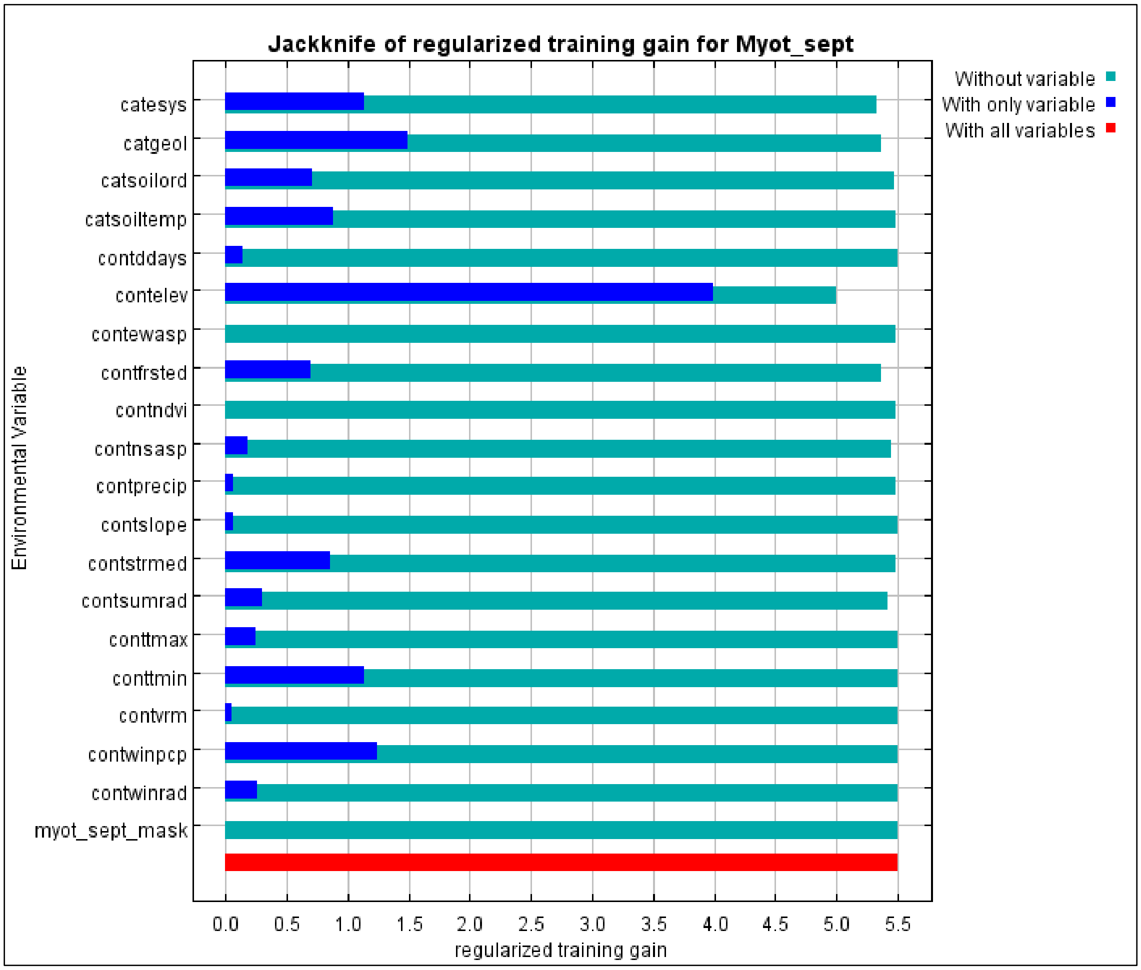
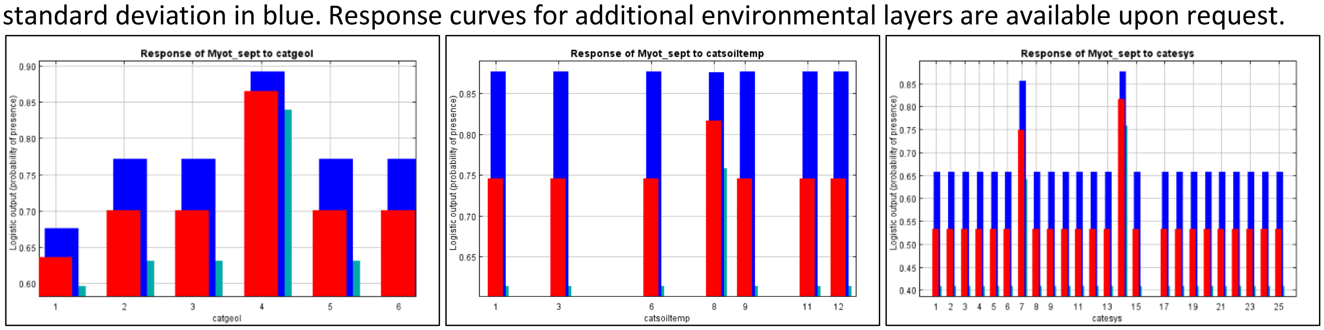


Figure 2. Response curves for the top three contributing environmental layers, mean value in red, +/- one standard deviation in blue. Response curves for additional environmental layers are available upon request.



Inductive Model Map Outputs

Figure 3. Continuous habitat suitability model output (logistic scale).

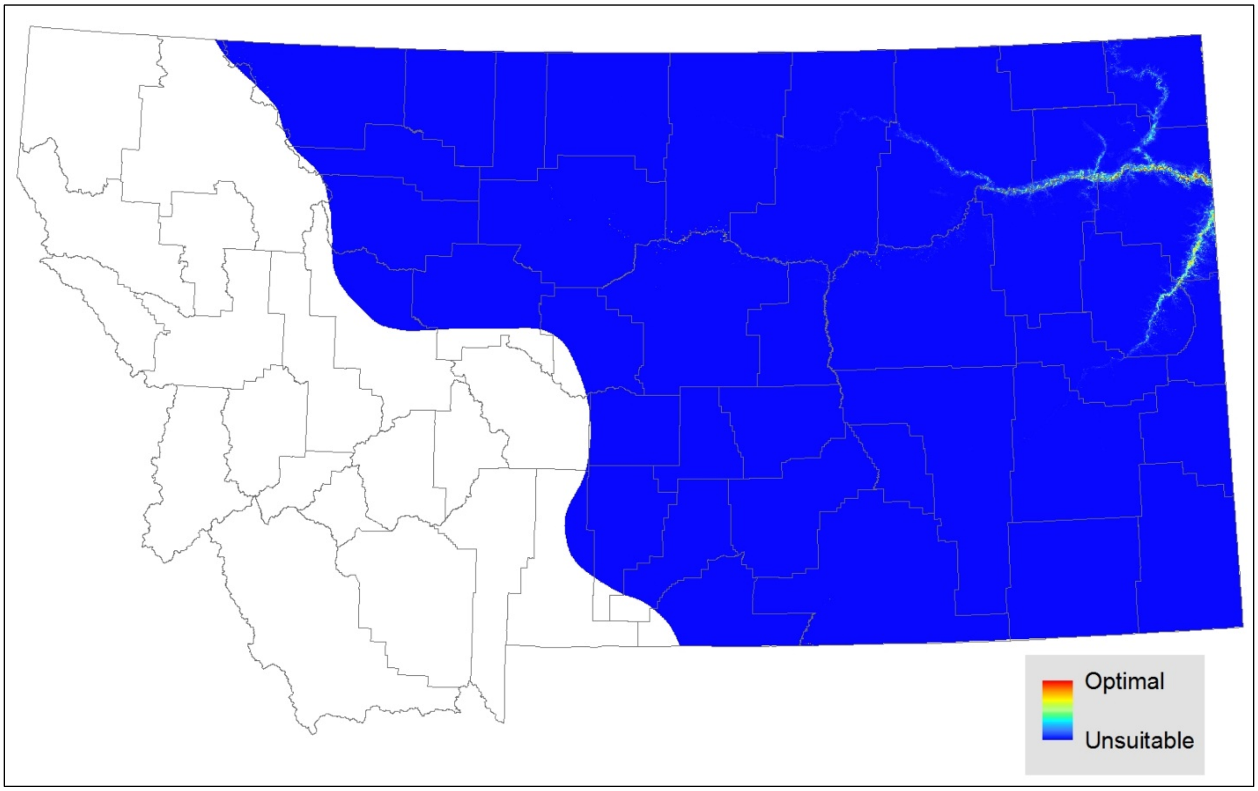


Figure 4. Standard deviation in the model output across the averaged models.

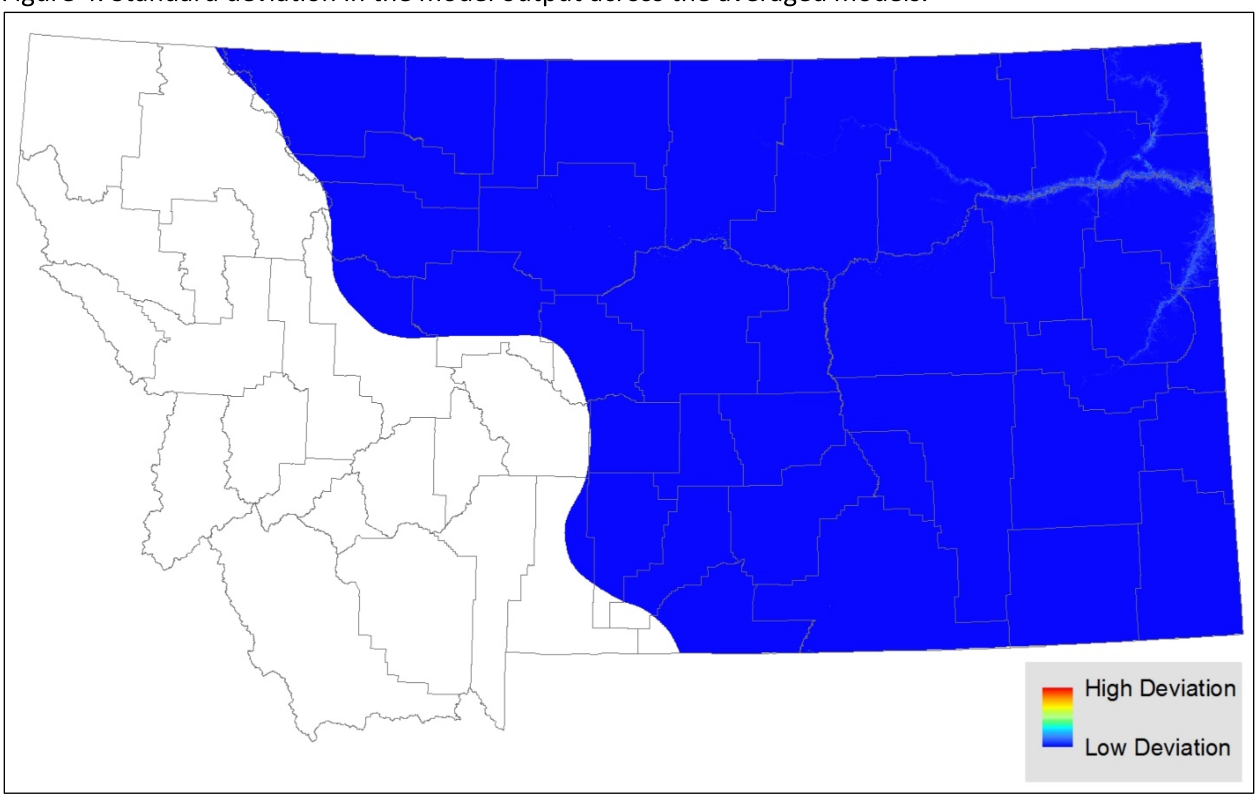


Figure 5. Continuous habitat suitability model output with the 8 observations used for modeling.

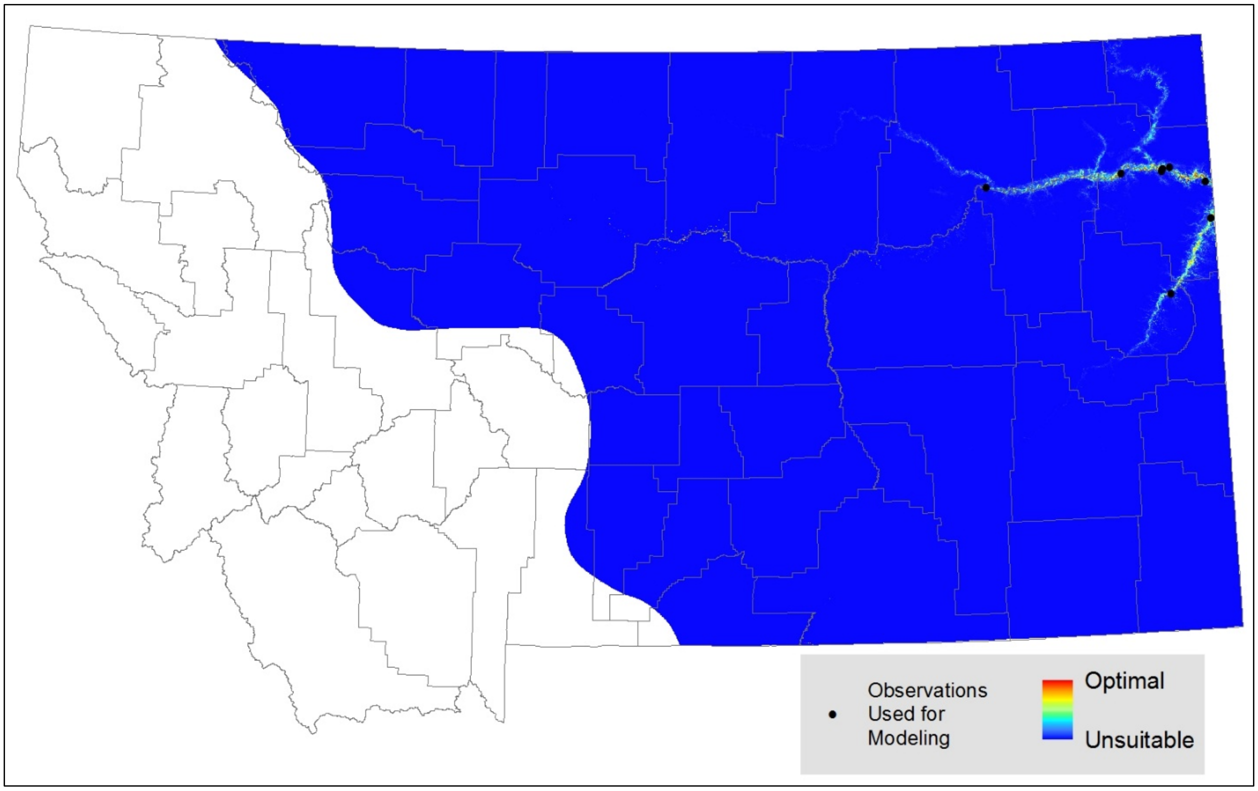


Figure 6. Continuous habitat suitability model output with relative deviance for each observation. Symbol size corresponds to the difference between 1.0 and the optimal, moderate, and low habitat suitability threshold.

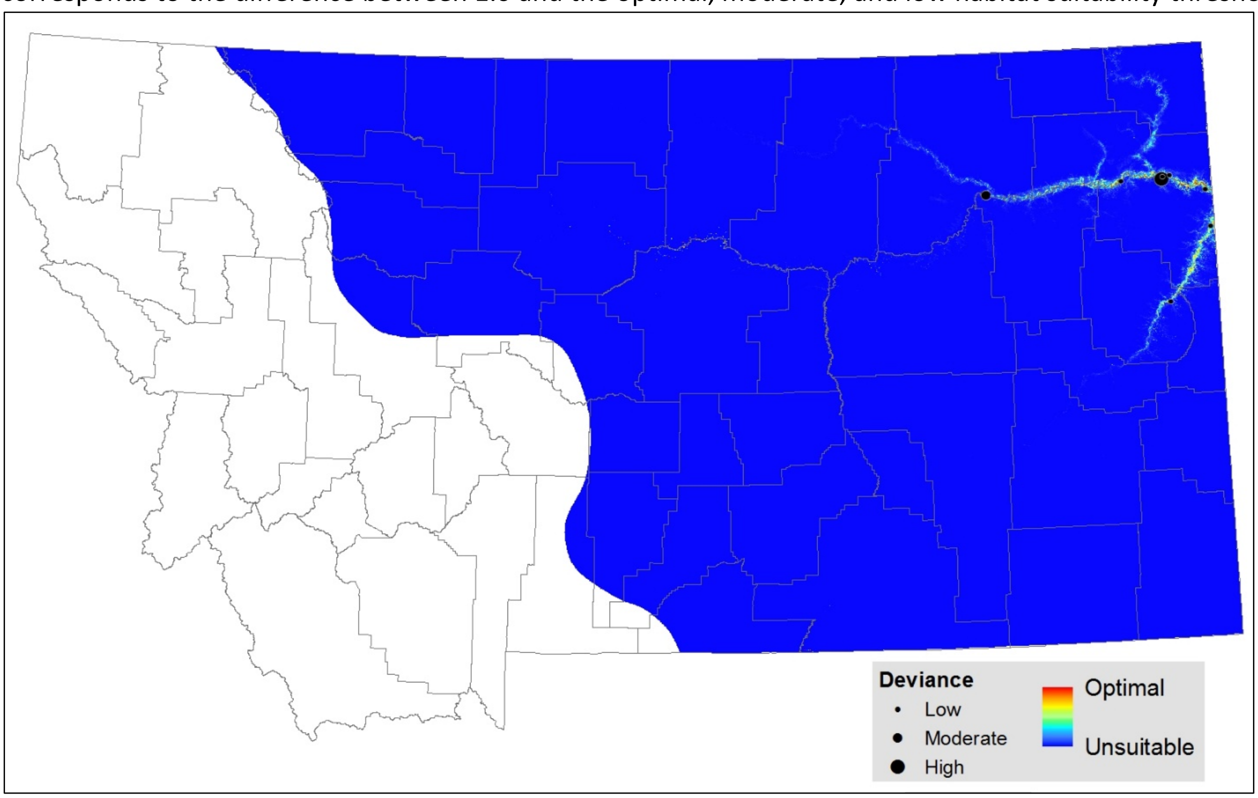


Figure 7. Continuous habitat suitability model output with all 10 observations (black) and survey locations that could have detected the species (gray).

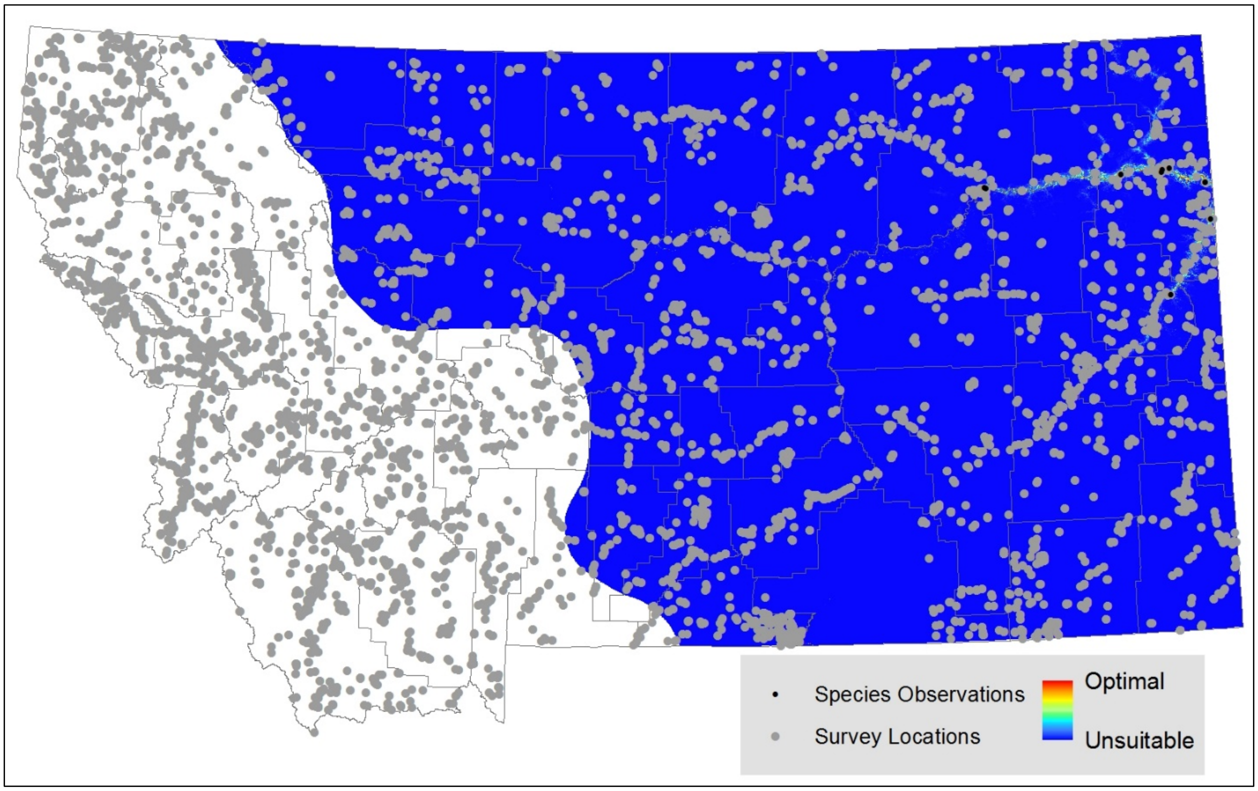


Figure 8. Model output classified into habitat suitability classes.

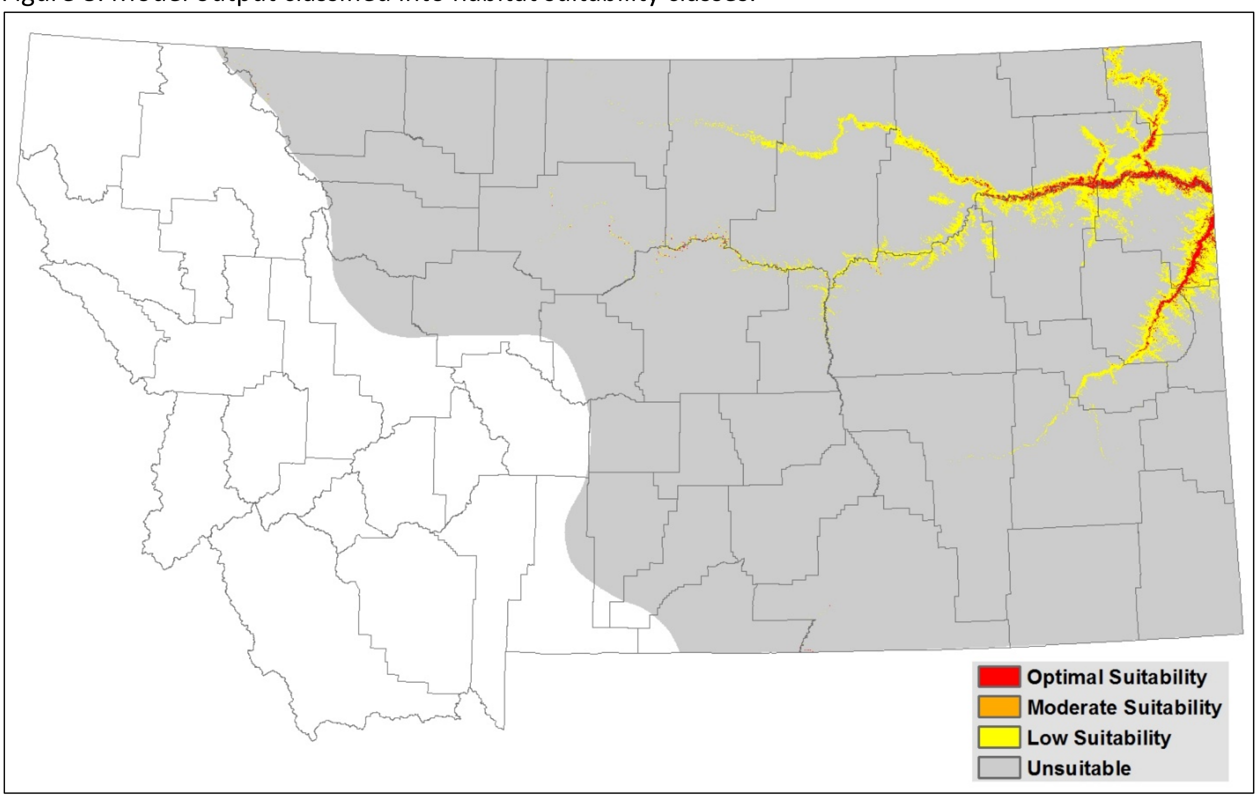
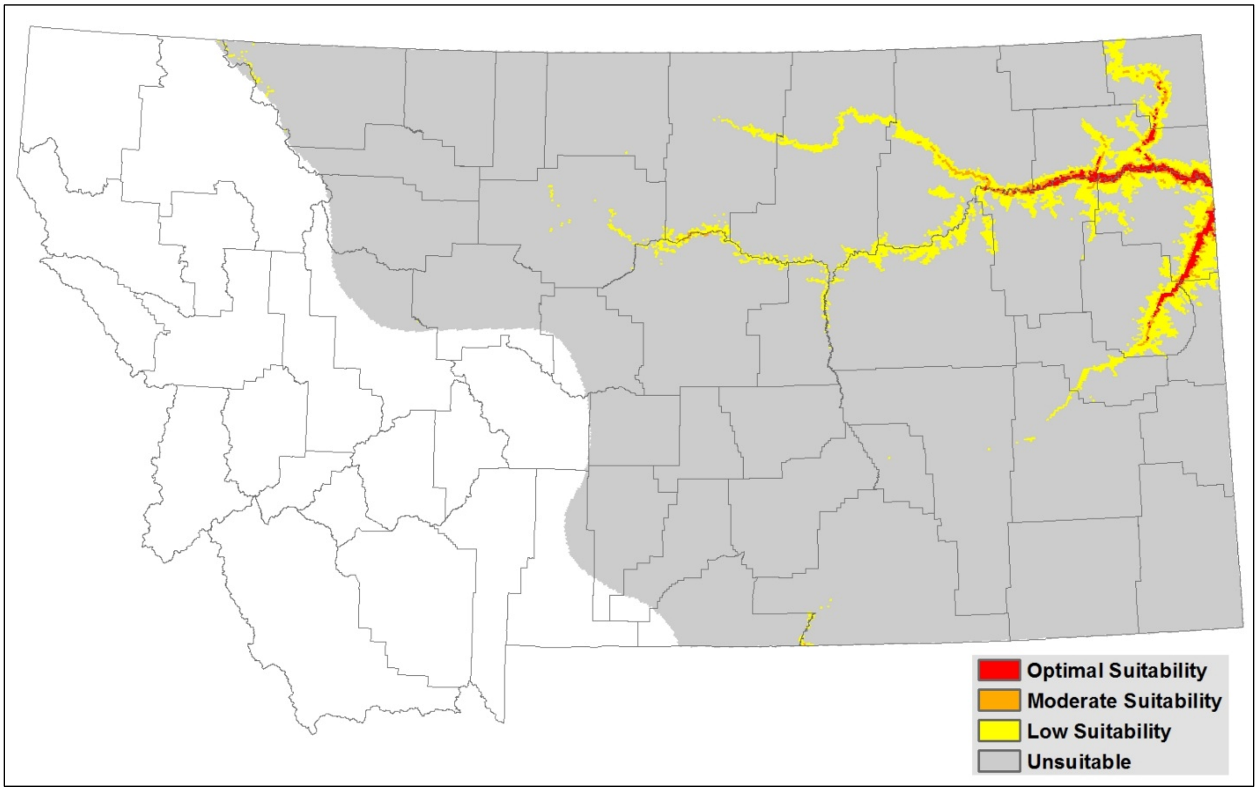


Figure 9. Model output classified into habitat suitability classes and aggregated into hexagons at a scale of 259 hectares per hexagon. This is the finest scale suggested for management decisions and survey planning.



Deductive Modeling

Model Limitations and Suggested Uses

Species associations with ecological systems should be used to generate lists of potential species that may occupy broader landscapes for the purposes of landscape-level planning. Users of this information should be aware that the land cover data used to generate species associations was only intended to be used at broader landscape scales. Land cover mapping accuracy is particularly problematic when the systems occur as small patches or where the land cover types have been altered over the past decade. Thus, particular caution should be used when using the associations in assessments of smaller areas (e.g. less than one quarter of a public land survey system (PLSS) section, <64 hectares). Model outputs should not be used in place of on-the-ground surveys for species, and wildlife and land management agency biologists should be consulted about the value of using these associations to guide habitat management decisions for regional planning efforts or local projects. See Suggested Contacts for State and Federal Natural Resource Agencies attached to this document. Data used in model evaluation often have locational uncertainties that exceed the 30-meter pixel size of the land cover dataset, potentially intersecting incorrect ecological systems. Additionally, the habitat within a pixel may have been assigned to the wrong ecological system or the habitat may have been modified. As a result, evaluation metrics may be skewed low, especially for species occupying ecotones or patchy ecological systems. Finally, users should note that ecological systems associated with a species are only mapped within the range of that species, although portions of that ecological system may occur elsewhere.

Deductive Model Methods

Modeling Process

This model is based on the 2016 statewide land cover classifications at 30×30 meter raster pixels (http://geoinfo.msl.mt.gov/msdi/land_use_land_cover). Level 3 ecological systems (90) were used for this model and these data were originally mapped at a scale of 1:100,000. In general, species were associated as using an ecological system if structural characteristics of used habitat documented in the literature were present in the ecological system or large numbers of point observations were associated with the ecological system. However, species were not associated with an ecological system if there was no support in the literature for use of structural characteristics in an ecological system, even if point observations were associated with that system. Species were either commonly associated, occasionally associated, or not associated with each ecological system. This assignment was based on the degree to which the structural characteristics of an ecological system matched the preferred structural habitat characteristics for each species in the literature. The percentage of observations associated with each ecological system relative to the percent of Montana covered by each ecological system was also used to guide assignments of habitat quality. Associations are shown in Table 6.

Model Outputs and Evaluation

The model output is a spatial dataset of categorical habitat suitability based on ecological system associations (commonly or occasionally associated) within the species' presumed range (Figure 10) and resulting tabular estimates of the area of commonly and occasionally associated habitat (Table 7). We evaluated this model output based on known or potential distribution and habitat use in Montana and absolute validation indices (AVI) (Hirzel et al. 2006, Ecological Modelling 199:142-152) using presence-only data (Table 8).

Deductive Model Results

Table 6: Ecological Systems Associated with Northern Myotis

Ecological System	Code	Association	Count[a]
Great Plains Floodplain	9159	Common	4
Open Water	11	Common	0
Great Plains Wooded Draw and Ravine	4328	Common	0

[a] A count of the observation records intersecting each ecological system, based on the 8 observation records used in the inductive model (see Table 1). This may be zero if the number of observations is low or if the ecological system is patchy.

Table 7: Area of Range and Ecological System (ES) Classes

Measure	Value
Area of entire modeled range (percent of Montana)	254,221.26 km^2 (66.8%)
Area of Commonly and Occasionally Associated ES	3,744.0 km^2
Area of Commonly Associated ES	3,744.0 km^2
Area of Occasionally Associated ES	0.0 km^2

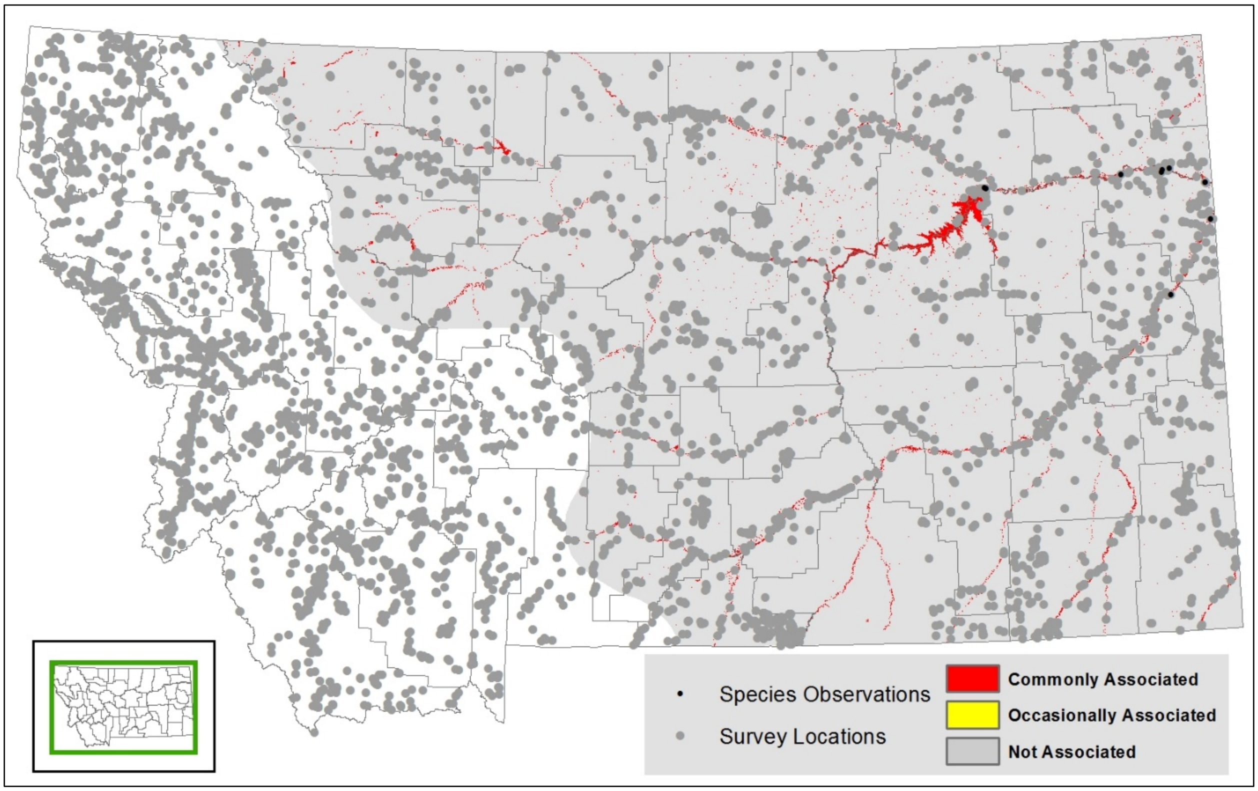
Table 8: Evaluation Metrics

Metric	Value
Commonly and Occasionally Associated ES AVI[a]	50.0%
Commonly Associated ES AVI[a]	50.0%
Occasionally Associated ES AVI[a]	0.0%

[a] Absolute Validation Index: The proportion of test locations that fall within the class(es).

Deductive Model Map Output

Figure 10. Deductive model output classified into habitat associations.



Suggested Contacts for Natural Resource Agencies

As required by Montana statute (MCA 90-15), the Montana Natural Heritage Program works with state, federal, tribal, nongovernmental organizations, and private partners to ensure that the latest animal and plant distribution and status information is incorporated into our databases so that it can be used to inform a variety of planning processes and management decisions. In addition to the information you receive from us, we encourage you to contact state, federal, and tribal resource management agencies in the area where your project is located. They may have additional data or management guidelines relevant to your efforts. In particular, we encourage you to contact the Montana Department of Fish, Wildlife, and Parks for the latest data and management information regarding hunted and high profile management species and to use the U.S. Fish and Wildlife Service's Information Planning and Conservation (IPAC) website http://ecos.fws.gov/ipac/ regarding U.S. Endangered Species Act listed Threatened, Endangered, or Candidate species.

For your convenience, we have compiled a list of relevant agency contacts and links below:

Montana Fish, Wildlife, and Parks

Fish Species	Zachary Shattuck zshattuck@mt.gov (406) 444-1231 or Lee Nelson leenelson@mt.gov (406) 444-2447
American Bison Black-footed Ferret Black-tailed Prairie Dog Bald Eagle Golden Eagle Common Loon Least Tern Piping Plover Whooping Crane	Lauri Hanauska-Brown LHanauska-Brown@mt.gov (406) 444-5209
Grizzly Bear Greater Sage Grouse Trumpeter Swan Big Game Upland Game Birds Furbearers	John Vore jvore@mt.gov (406) 444-5209
Managed Terrestrial Game and Nongame Animal Data	Smith Wells – MFWP Data Analyst smith.wells@mt.gov (406) 444-3759
Fisheries Data	Adam Petersen – MFWP Fish Data Manager apetersen@mt.gov (406) 444-1275
Wildlife and Fisheries Scientific Collector's Permits	http://fwp.mt.gov/doingBusiness/licenses/scientificWildlife/ Karen Speeg for Wildlife kspeeg@mt.gov (406) 444-2612 Kim Wedde for Fisheries kim.wedde@mt.gov (406) 444-5594
Fish and Wildlife Recommendations for Subdivision Development	Renee Lemon RLemon@mt.gov (406) 444-3738) See also: http://fwp.mt.gov/fishAndWildlife/livingWithWildlife/buildingWithWildlife/subdivisionRecommendations/
Regional Contacts 	Region 1 (Kalispell) (406) 752-5501 Region 2 (Missoula) (406) 542-5500 Region 3 (Bozeman) (406) 994-4042 Region 4 (Great Falls) (406) 454-5840 Region 5 (Billings) (406) 247-2940 Region 6 (Glasgow) (406) 228-3700 Region 7 (Miles City) (406) 234-0900

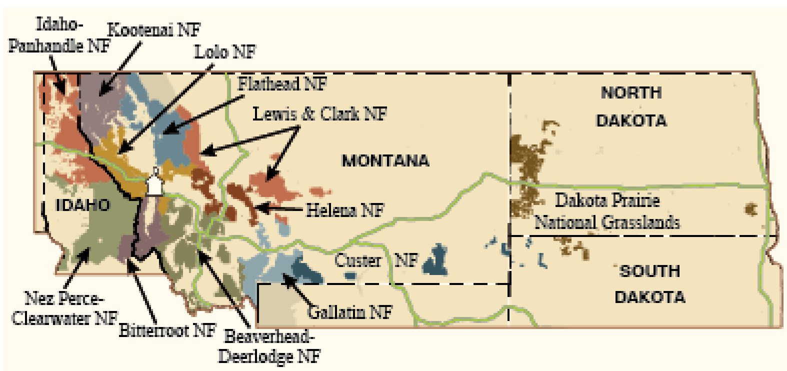
U.S. Fish and Wildlife Service
Information Planning and Conservation (IPAC) website: http://ecos.fws.gov/ipac/
Montana Ecological Services Field Office: http://www.fws.gov/montanafieldoffice/ (406) 449-5225

Bureau of Land Management

Montana Field Office Contacts:

Billings:	(406) 896-5013
Butte:	(406) 533-7600
Dillon:	(406) 683-8000
Glasgow:	(406) 228-3750
Havre:	(406) 262-2820
Lewistown:	(406) 538-1900
Malta:	(406) 654-5100
Miles City:	(406) 233-2800
Missoula:	(406) 329-3914

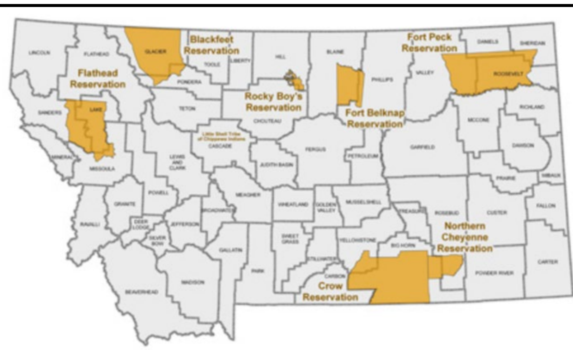
United States Forest Service



Regional Office – Missoula, Montana Contacts

Wildlife Program Leader:	Tammy Fletcher	tammyfletcher@fs.fed.us	(406) 329-3588
Wildlife Ecologist:	Cara Staab	cstaab@fs.fed.us	(406) 329-3677
Fish Program Leader:	Scott Spaulding	scottspaulding@fs.fed.us	(406) 329-3287
Fish Ecologist:	Cameron Thomas	cathomas@fs.fed.us	(406) 329-3087
TES Program:	Lydia Allen	lrallen@fs.fed.us	(406) 329-3558
Interagency Grizzly Bear Coordinator:	Scott Jackson	sjackson03@fs.fed.us	(406) 329-3664
Regional Botanist:	Steve Shelly	sshelly@fs.fed.us	(406) 329-3041

Tribal Nations



- Assiniboine & Gros Ventre Tribes – Fort Belknap Reservation
- Assiniboine & Sioux Tribes – Fort Peck Reservation
- Blackfeet Tribe - Blackfeet Reservation
- Chippewa Creek Tribe - Rocky Boy's Reservation
- Crow Tribe – Crow Reservation
- Little Shell Chippewa Tribe
- Northern Cheyenne Tribe – Northern Cheyenne Reservation
- Salish & Kootenai Tribes - Flathead Reservation